EFFECTS OF PROSODY-ALTERED FEEDBACK ON STUTTERING FREQUENCY AND RELATED SPEECH BEHAVIORS

By

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A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

2009

To Su Jin who has supported me to her best and loved me as I am

ACKNOWLEDGMENTS

My first thanks go out to Dr. Kenneth Logan, who is my academic advisor at UF. I don't know how to describe the way he has been supported me as my teacher and mentor. He has helped and guided me to his best, always more than I expected. Whenever I ask for help, he always found the time to listen to and counsel me. Since I started doctoral program without any basic background about communication sciences and disorders, he has always helped and guided me to get on the right direction. During my doctoral years with him, I had many chances to learn from him about how to be a good researcher and a good teacher. He was a perfect role model for me to follow and I thought I really wanted to be a good mentor just like him. He was also a great helper, especially when I began and developed my dissertation project. Without him, I could not finish this work.

I also give thanks from my heart to my supervisory committee Dr. Linda Lombardino, Dr. Ratree Wayland, and Dr. Lori Altmann. Each of them provided valuable feedback and support for my work. Especially, Dr. Lombardino has been so kind and given much interest in me and my work like a mother does to her son. Dr. Wayland also provided me with her valuable insight to further develop the work and plan for future study. Dr. Altmann also gave me precious help and encouraged me to keep going. Without their help, again, I could not finish my work.

I want to give thanks to my family for their endless support. Especially, my wife, Sujin, has been my great partner and helper since I met and fell in love with her ten years ago. Even though I am "older" than her, she has been always my big counselor and priceless guider whenever I was in trouble and didn't know how to do the right thing. Most of all, I want to give thanks to her for loving me just as I am, even though I am not a perfect husband for her. I also want to give thanks to my precious and lovely two daughters, Hee young, and Seoyoung. They

have been always my joy more than I describe. When I was discouraged or depressed for heavy load of work, they have always given me big hugs and priceless smiles.

As well, I want to say thanks to all members of Korean Baptist Church of Gainesville. They have always supported me and my family spiritually and sometimes, financially. I will never forget their love for me and my family. Especially, I want to give thanks to Paster Heeyoung Sohn and Paster Minseok Sohn for their heavenly love and endless support for me. They have been always my spiritual fathers and mentors.

Lastly, I want to say thanks to my mother, who has been alone without her husband for the past ten years. She has dedicated herself to her son. The only thing I can give her back now is my tears as tokens of gratitude. Now, I just want to say to her, “I love you, my mother”.

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December, 2009

Chair: Kenneth J. Logan
Major: Communication Sciences and Disorders

It has been well demonstrated that choral speech significantly reduces stuttering frequency in adults who stutter (Andrews et al., 1982; Ingham & Packman, 1979; Rami, 2000, 2005). This finding has led to the development of assistive devices in which speakers who stutter enhance their fluency by speaking while hearing their own voice at a slight delay or at higher or lower pitch than normal. The underlying mechanisms for this effect remain unclear, however. The main purpose of the present study was to assess the role of prosodic cues in the choral speech effect. Adult speakers produced sentences under several choral speaking conditions, including ones that featured modifications of prosodic information, namely pitch contour and durational patterning. Effects of these prosodic modifications upon speech fluency, speech rate, sentence production accuracy, and participants' self-ratings of speech naturalness were assessed. Speech production characteristics in the prosody-altered feedback were compared to those in delayed auditory and frequency-altered conditions as well as in a conversational babble condition which lacked clear segmental and prosodic cues. Results showed that the availability and accuracy of prosodic information (i.e., pitch contour, word durational pattern) did not affect the extent to which choral auditory feedback enhances fluency. In addition, it was shown that alterations in duration-based prosodic feedback do not affect speech fluency differently than alterations in pitch-based

prosodic feedback do. That is, participants who stutter spoke as fluently while receiving temporally-altered choral feedback as while receiving pitch contour-altered choral feedback. Furthermore, it was shown that participants who stutter spoke as fluently when speaking under prosody-altered choral feedback as when speaking under DAF, FAF, and typical choral speaking conditions. Even though participants who stutter showed more entrainment to choral speech and it appears that they benefit from choral speech than typical speakers do, finally, it was argued that the entrainment does not seem to be the main mechanism in explaining the fluency enhancing effects observed during choral speech. Several alternative hypotheses are proposed, including ones involving auditory cortex activation to explain fluency enhancing effects of participants who stutter.

CHAPTER 1
INTRODUCTION

Prosody involves undulating temporal patterns in tone, tempo, and loudness that constitute the rhythm or tune of a spoken message (Cray & Tallman, 1993, Warren, 2000). A variety of studies have linked prosodic factors to stuttering. For example, it has been demonstrated that stuttering tends to occur more often on words that bear lexical or phrasal stress than on words that do not (Arbisi-Kelm, 2006; Bergmann, 1986; Brown, 1938; Klouda & Cooper, 1988; Natke, Grosser, Sandrieser, & Kalveram, 2002; Prins, Hubbard, & Krause, 1991; Wingate, 1984, 1988). Consistent with this, some researchers have argued that stuttering is essentially a timing disorder that is manifested in the speech motor control system, with the central problem being a deficit in either the capacity to generate temporal programs that guide action (Kent, 1984) or the ability to integrate segmental and prosodic representations prior to speech generation (Perkins, Kent, & Curlee, 1991). The exact role of prosody in the speech fluency of persons who stutter, however, remains unclear.

As has been well demonstrated (Andrews et al., 1982; Ingham & Packman, 1979; Rami, 2000, Kalinowski et al., 1993; Kalinowski & Saltuklaroglu, 2003; Lincoln et al., 2006), speakers who stutter exhibit marked improvements in fluency when speaking while receiving some types of auditory feedback. Specifically, speakers who stutter often show substantial – and sometimes complete – reduction in stuttering symptoms when speaking while receiving delayed or frequency-altered auditory feedback (i.e., DAF, FAF), or speaking while receiving another speaker's choral voice feedback (i.e., choral speech). However, there is no clear-cut explanation about the mechanism underlying these phenomena. Even though it can be noted that alterations either in temporal structure (as in DAF) or in frequency (as in FAF) yield similar fluency enhancement effects (Kalinowski et al., 1993), few studies have been conducted on prosodic

alterations and their effects on fluency under auditory feedback conditions. Thus, the main purpose of the present study is to investigate role of prosody in speech fluency by studying the effect of prosodic manipulations upon speech fluency during choral reading conditions.

In the present study, we examined whether the fluency enhancing effect observed under choral reading conditions continues to be observed even when prosodic cues (i.e., pitch contour, durational patterns) in the choral model signal are altered or mismatched, and we compared the changes in speech fluency noted in these conditions to changes in speech fluency noted in other fluency enhancing conditions, namely DAF and FAF. This approach should lead to insight on the mechanisms underlying the role of prosody in the problem of stuttering as well as the factors that are associated with the reduction and/or elimination of stuttering in certain auditory feedback conditions. Along with this, we expect that the present study will clarify the relative contributions of segmental and supra-segmental (or prosodic) cues in the fluency enhancing effects observed under choral auditory feedback for speakers who stutter.

Stuttering: Overview

Definition

At first glance, people tend to believe that they know what stuttering is, but upon closer examination, it is not easy to describe the disorder in an objective and comprehensive way. Traditionally, defining stuttering has mainly involved exploring the measurable dimensions of the disorder, such as its primary symptoms, frequency, degree, and severity (Bloodstein, 1995). In general, stuttering has been defined as a verbal disorder in which fluency of speech is impaired by interruptions or blockages, and is particularly characterized by sound or syllable repetitions, prolonged sounds, and blocks (or breaks) in the forward flow of speech (Bloodstein, 1987, 1995; Wingate, 1964). Over the years, some clinicians have used quantitative concepts such as the frequency or duration of these disfluency types to diagnose and, thus, define disorder.

In terms of disfluency frequency, for example, some clinicians (e.g., Conture, 2001) have used a threshold of 3 within-word disfluencies per 100 words for diagnosing the disorders (with within-word disfluencies consisting of part-word repetitions, word repetitions, sound prolongation, and blocks). Less often, clinicians (e.g., Guitar, 2006) have used a threshold of 10 disfluencies of any type per 100 words as a measuring marker for the identification of stuttering. The latter criterion has not been used as often, however, because it potentially can include types of fluency impairment other than stuttering. Of course, most speakers who stutter exhibit disfluency frequencies that are considerably greater than these minimum criteria, and the variability of the symptoms can be quite high when examined interpersonally or across different speaking conditions (Bloodstein, 1995; Bloodstein & Bernstein Ratner, 2006).

Further, it has been noted that stuttering is not just the intermittent impairment of fluency because the disorder is also evident in other aspects of speech such as the rate, pitch, loudness, articulation, facial expression, and even postural adjustments of the speaker (Bloodstein, 1995). Some involuntary and abnormal movements associated with stuttering, which are often termed secondary behaviors, have been observed in persons who stutter. Examples of these secondary movements include eye-blinking, frowning, wrinkling of the forehead, sudden exhalation of breath, and distortion of the mouth muscles (Bloodstein, 1995; Conture, 2001). Even though it is not easy to identify the immediate cause of the movements, many researchers agree that the involuntary movements can be understood as responses of persons who stutter to the challenge of trying to produce fluent speech (Bloodstein & Bernstein Ratner, 2006; Wingate, 1964). Furthermore, some abnormalities have been reported even in perceptually “fluent” speech of persons who stutter (Bloodstein & Bernstein Ratner, 2006). Examples of those abnormalities

include the speakers' incorrect use of the larynx (Gautheron et al., 1973), centralization of vowels' formant frequencies (Klich & May, 1982), and a slower speech rate (Bloodstein, 1944).

Despite the fact that interpersonal or situational variability in stuttering are relatively high, some basic characteristics that can be generalized across persons who stutter have been identified and considered as "facts" about stuttering (Conture, 2001). First, in terms of its onset, the outwardly observable symptoms of stuttering are typically observed to begin during childhood, roughly around age 3 to 5 years (Yairi, 1983). Second, the disorder is more common among boys than it is among girls, with a sex ratio of approximately 3:1 among schoolchildren (Kidd, Kidd, & Records, 1978; Yairi & Ambrose, 2005). Third, about two-thirds of all people who stutter have at least one other family member who also stutters, a finding which has been used to support the idea that stuttering has a genetic basis (Ambrose & Cox, 1997; Andrews & Harris, 1964; Buck et al., 2002; Wiswanath, Lee, & Chakraborty, 2004; Yairi & Ambrose, 2005). Fourth, most children who begin to stutter eventually seem to "outgrow" the disorder. It has been reported that as many as four out of every five children who stutter recover with or without formal treatment (Andrews & Harris, 1964; Panelli, McFarlane, & Shipley, 1978; Yairi & Ambrose, 1992, 1996a). Fifth, it has been shown that stuttering is more often observed in specific locations of utterance such as word-initial sounds or syllables, especially those within multi-syllable, low-frequency or low-usage words in an utterance (Bernstein Ratner, 1997). Sentence-level factors such as the overall length and grammatical complexity of an utterance have been shown to increase the likelihood of stuttering behavior, as well (Bernstein Ratner & Sih, 1987; Gaines, Runyan, & Meyers, 1991; Melnick & Conture, 2000; Yaruss, 1999; Zackheim & Conture, 2003). Lastly, many children who stutter seem to present with concomitant speech and language problems, particularly in the area of phonology (Louko, Edwards, & Conture,

1990; St. Louis, 1991; Yairi et al., 1996). It should be noted, however, that some (e.g., Nippold, 1990) have challenged the latter claim by suggesting that the apparent high rate of concomitant problems merely reflects sampling error.

Stuttering as a Linguistically-Conditioned Disorder

The role of language has long been considered important in theories and research on stuttering (Bernstein Ratner, 1997). It has been well documented that the frequency and location of stuttering are closely associated with various linguistic factors. As mentioned above, stuttering tends to occur more often in conjunction with the initial position of linguistic structures or units (Au-Young, Howell, & Pilgrim, 1998; Brown, 1945; Wingate, 1979). With adults who stutter, stuttering is more frequently observed on content words (e.g., nouns, adjectives, adverbs) than it is on function words (e.g., prepositions, conjunctions, articles). However, the distribution of stuttering is reversed for children who stutter (Au-Young, Howell, & Pilgrim, 1998; Au-Yeung, Gomez, & Howell, 2003; Dworzynski & Howell, 2004). Moreover, syntactically-complex sentences are more likely to contain stuttered words than syntactically-simple sentences, even when factors like overall sentence length are controlled (Bernstein Ratner & Sih, 1987; Kadi-Hanifi & Howell, 1992). Emphasizing the linguistic factors on stuttering, some researchers (e.g., Bernstein Ratner, 1997) have argued that stuttering is a linguistically-conditioned disorder, and it reflects failure in the sentence production process, rather than solely being the result of speech motor execution constraints. In this view, some researchers have proposed that the disorder is closely linked to a difficulty in ability to encode either syntactic units (Bloodstein, 1981, 2002), while others have proposed that the deficit involves the ability to select phonological or segmental units (Postma & Kolk 1993, 1997).

Stuttering as a Deficit of Speech Motor Control

Despite some limitations in research methodologies and some inconsistencies in the results of studies (Bloodstein, 1995), it has been relatively well documented that individuals who stutter have anomalies in the motoric processes related to speech and nonspeech activities (Adams & Hayden, 1976; Packman, Code & Onslow, 2007; Maske-Cash & Curlee, 1995; Max, Caruso, & Gracco, 2003; Smits-Bandstra, De Nil, & Rochon, 2006). Examples of motoric anomalies reported include a slower initiation and termination of the vowel production (Adams & Hayden, 1976) and slower manual finger movements (Code & Onslow, 2007). Furthermore, evidence from brain imaging studies has indicated that motor regions of persons who stutter, such as the primary motor cortex, the supplementary motor area (SMA), and superior lateral premotor area, are over-activated relative to those of normally fluent speakers (Brown et al., 2005; DeNil, Kroll, Kapur, & Houle, 1998; Fox et al. 1996; Fox et al., 2000; Ingham et al., 2000; Neumann et al., 2003; Van Borsel et al., 2003, Watkins et al., 2008). Accordingly, a number of researchers (Ludlow & Loucks, 2003; Packman, Code, & Onslow, 2007; Smit-Bandstra, DeNil, & Rochon, 2006) have argued that stuttering is closely linked to a deficit of speech motor control, rather than a difficulty in linguistic encoding per se. Within the motor-related perspective of stuttering, it can be noted that linguistic processing or formulation is a part of the condition in which stuttering behaviors are induced, rather than an immediate cause of the disorder.

Prosody: Overview

Prosody and its General Role on Speech Production

Although not easy to define, prosody can be understood as the suprasegmental features or the combinations of fundamental frequency (or F0), duration, and intensity that contribute to the melody or rhythm of speech production by undulating tone, tempo, and loudness of a spoken message (Cray & Tallman, 1993; Warren, 2000). To fully capture the prosodic features of

connected speech, some researchers (e.g., Karniol, 1995) have identified melody and rhythm as the two main prosodic aspects. With respect to speech production, melody mainly relates to an utterance's tonal patterns and it is mainly expressed by the fundamental frequency contour. Alternatively, rhythm is concerned with the relative duration of prosodic units such as syllables, words, and pauses as well as the interrelations among these units within an utterance.

As some researchers (Gerken & McGregor, 1998; Warren, 2000) have pointed out, prosody has not always been considered to be as important as some other components of language (i.e., syntax, phonology, semantics). This is somewhat surprising because prosody, like the other aspects of language, can carry meaning, often by qualifying the information contained in the syllable, word, and phrase sequences, and sometimes by negating the meaning conveyed in the semantic features (Wingate, 1984; Warren, 2000). Emotional and attitude-related pragmatic functions of speech can be also identified from intonation contour and from the range of fundamental frequency (Ladd, Silverman, Tolkmitt, Bergmann, & Scherer, 1985).

Furthermore, several modern psychological theories of language production have addressed the role of prosody on speech generation (Bock, 1982; Dell, 1986; Fromkin, 1971; Keating & Shattuck-Hufnagel, 2002; Levelt, 1989, 1999a, 1999b; Shattuck-Hufnagel, 1979, 1987), arguing that speech is generated or realized by the combination of segmental and prosodic information. It has been argued that segmental and prosodic information are two main components in speech, they must be aligned with one another prior to speech initiation, and the specifications of the alignment or the phonetic plans are at last expressed in speech through changes in muscle movement.

Prosody and its Association with Speech Disorders

As discussed in some studies (cf. Hargrove, 1997), abnormal prosody, or dysprosody, may negatively influence the intelligibility of a spoken message. As a common example, non-native

speakers of English who still retain the prosody of their native language when speaking English will likely have reduced intelligibility when interacting with native-English speakers (cf. Anderson-Hsieh, Johnson, & Koehler, 1992; Munro & Derwing, 1999). Atypical prosody can be also found in some disorders that affect verbal communication. Examples include hearing impairment (e.g., Lenden & Flipsen, 2007), developmental or neurological language disorders (e.g., Catter et al., 2006; Gerken & McGregor, 1998), and speech motor disorders (e.g., Owens et al., 2000; Van Putten & Walker, 2003). Especially, dysarthria and apraxia have been relatively well investigated as common examples of aprosodic speech disorders and it has been found that people with the impairments demonstrate abnormal abilities in prosody such as inappropriate stress pattern and a slower speech.

Many researchers have examined stuttering from a prosodic perspective, and have provided considerable evidence to indicate that prosody is closely linked to stuttering and its associated symptoms. First of all, it has been continuously shown that stuttering tends to occur more often in conjunction with words that bear lexical or phrasal stress within utterances than words that do not (Arbisi-Kelm, 2006; Bergman, 1986; Brown, 1938; Klouda & Cooper, 1988; Natke, Grooser, Sandrieser, & Kalveram, 2002; Prins, Hubbard, & Krause, 1991; Wingate, 1984). Moreover, prosodic factors have been incorporated in several prominent theories of stuttering. For example, Kent (1984) proposed that stuttering reflects impairment in the capacity to generate temporal programs that underlie sequential movement. Similarly, Perkins, Kent, and Curlee (1991) proposed that stuttering involves a breakdown in the integration or alignment of segmental and prosodic representations prior to speech initiation. Despite this preliminary work, however, the exact role of prosody in the speech fluency of speakers who stutter remains unclear.

Prosodic Expression: Stress, Intonation, and Rhythm

To provide the reader with a better understanding of prosody and its role in speech production, some important notions of prosody in speech production will be further discussed. Prosody can be conceptualized as consisting of various features. In connected speech, these prosodic features can be used in isolation or in various combinations to make a particular prosodic expression. Of these, the chief features, as perceived, are pitch, loudness, and duration (Warren, 2000). In connected speech, these prosodic variables are integral to dimensions of the speech stream that are identified as stress, intonation (or pitch contour), and rhythmic or timing pattern of speech (Cray & Tallman, 1993; Warren, 2000).

Stress as an expression of prosody has been referred to as the relative prominence of syllables that are mainly signaled by the prosodic features of length, loudness, and pitch (Spencer, 1995). Basically, it is known that stressed syllables are longer, louder, and higher in pitch than unstressed ones. Differences in stress within a word often lead to differences either in grammaticality of the word (e.g., import [noun] vs. import [verb]) or in segmental quality or vowel type of the word (e.g., convict [noun] vs. convict [verb]).

Within utterances larger than the single word, furthermore, it has been noted that there are further differences in prominence, which give rise to degrees of stress (Liberman, 1975; Liberman & Prince, 1987; Selkirk, 1984, 1996). When several words are combined to form compounds, phrases, or sentences, it can be assumed that in addition to the relative prominence of syllables, the relative prominence of words as larger prosodic units needs to be considered as well in terms of which words are more prominent than others (Spencer, 1995). The relative prominence of words in the multiword domains is marked by particular F0 patterns, namely, pitch accents (Liberman, 1975; Liberman & Prince, 1977). Figure 1-1 shows an example of the stress pattern (e.g., She’s leaving Boston tomorrow). The example is similar to work described

by Warren (2000). Stress pattern for the example sentence is based on Autosegmental Phonology, which was fully explained and described by Liberman and colleagues (Liberman, 1975; Liberman & Prince, 1977).

As shown at the bottom of Figure 1-1(A), every syllable in the sentence bears a minimum one degree of prominence, which is represented by one grid mark (*) above every syllable. Then, every lexically-stressed syllable of the multi-syllabic words (e.g., leaving, Boston, tomorrow) is marked by an additional grid mark. Because it is typically the case that content words are more prominent than function words, each of the content words (e.g., leaving, Boston, tomorrow) are further marked by the additional grid mark on each of their lexically-stressed syllables. Among these content words, two (e.g., leaving, tomorrow) are more prominent so pitch accent, which is determined by phrasal properties, falls on each of their lexically-stressed syllables. Given no special emphasis or focus on a particular word in the sentence, finally, the nuclear pitch accent falls on the lexically-stressed syllable of the rightmost content word (e.g., tomorrow) (Chomsky & Halle, 1968).

The prosodic pattern of an utterance can be also illustrated in a somewhat different way using schematic prosodic transcription (See Figure 1-1(B) for an example). In this case, the stress level of each syllable of an utterance is represented by dots (Warren, 2000). As demonstrated in Figure 1-(B), the nuclear pitch accent is again realized by pitch prominence on the lexically-stressed syllable of the rightmost content word and the pitch falls somewhat dramatically during the following unstressed syllable (e.g., -rrow) because in this example, the utterance can be considered a simple statement (i.e., declarative sentence). The step up in pitch from the unstressed syllable of the function word (e.g., she’s) results in pitch prominence on the stressed syllable of the following content word (e.g., lea-).

As demonstrated above, it can be argued that the level of stress and the placement of nuclear pitch accent form key aspects of phrasal prosody, and the phrasal stressing is determined on the basis of the relative prominence among words for the multiword domain of utterance (Ferreira, 1993; Warren, 2000). Discussing stuttering and its association with linguistic stress, Wingate (1984) also commented on phrasal stressing and word-to-word relationships and argued that phrasing stress is based on “the role played by certain words in relationship to other words in the utterance” (p. 223).

Another aspect of prosody that needs to be discussed here is intonation, which can be defined as the pattern of pitch changes over the course of an utterance (Lehiste, 1970; Warren, 2000). As is well known, certain patterns in intonation contribute to the meaning of utterances, particularly, in signaling declarative or interrogative sentences. Because of the terminal falling contour in pitch, for example, the earlier example (i.e., She’s leaving Boston tomorrow) can be signaled or interpreted as a simple statement. The rising contour at the same position, however, is likely for the sentence to be interpreted as a question. Furthermore, intonation can be a key marker to signal ”unfinished business” with a high terminal pitch (Lehiste, 1970; Warren, Grabe, & Nolan, 1995) or “contrastive focus” on a particular word(s) with a significant change in pitch (Eefting & Nooteboom, 1991; Fowler & Housum, 1987).

Lastly, the rhythm (i.e., the timing or durational pattern) of an utterance mainly concerns the relative duration of prosodic units (e.g., syllables, words, or pauses) and their interrelations with one another in the utterance (Karniol, 1995; Warren, 2000). Stressed syllables are typically longer in duration than their counterparts or unstressed syllables (Atkinson, 1973; Ferreira, 1993, 1996). Phrase-final words also tend to be longer in duration than words in other positions such as the phrase-medial or phrase-initial position (Ferreira, 1993; Nakatani, O’Connor, & Aston, 1981;

Wheeldon, 2000). This phenomenon is well known and is referred to as "phrasal-final lengthening effect". As shown in an example from Ferreira (1993) (e.g., The table that I thought was black tempted me. vs. The black table tempted me.), the word "black" of the former sentence is longer than the same word of the latter sentence because of its phrase-final location.

Prosody in the Models of Speech Generation

Levelt's Perspective (1989)

Even though it is not an easy task to explore and describe the exact process of speech generation, many researchers (Bock, 1982; Dell, 1986; Fromkin, 1971; Garrett, 1980; Levelt, 1989; Shattuck-Hufnagel, 1979, 1987) have argued that planning a sentence mainly involves the construction of successive levels of representations. In Levelt's (1989) view, in order to generate connected speech, a semantic or conceptual representation is assumed to be firstly constructed through a generating processor called the "conceptualizer". Subsequently, two linguistic representations, one involving syntactic information represented as "lemmas", and another involving phonological information represented as "lexemes", are generated through a second processor called the "formulator". Ultimately, the phonological representation is translated into a motor program to produce real speech through a final processor called the "articulator."

A number of researchers (Ferreira, 1993; Levelt, 1989; Keating & Shattuck-Hufnagel, 2002) have provided further explanations of prosody and its pattern generation for connected utterances. In order to explain the mechanism of prosody for connected speech, Levelt (1989) proposed a particular component called the Prosody Generator, which incrementally produces the metrical and intonational structure of connected utterances. According to Levelt, the prosodic component receives information available from the metrical and segmental spellout as well as from the surface structure and intonational meaning of the intended utterance. Through

integrating all information obtained from each of the components, the Prosody Generator produces the metrical and intonational properties of connected speech. Levelt's connected speech production and phonological encoding model is shown in Figure 1-2.

Ferreira's Perspective (1993)

Maintaining Levelt's (1989) assumption of a Prosody Generator, Ferreira (1993) subsequently proposed another mechanism to generate the prosodic pattern for connected speech. Differentiating word prosody and sentence prosody mechanisms, Ferreira argued that a spoken sentence is not simply a series of concatenated prosodic (metrical) patterns for individual words. In order to generate the prosodic pattern for the connected speech, she argued that not only the metrical patterns for each individual word but also the prosodic structure of the utterance need to be considered in an integrated way. Consistent with Levelt's earlier model (1989), Ferreira assumed that the procedure for utterances' prosodic generation is mainly executed through the Prosody Generator. Her explanation is made more explicit by using an example (e.g., The girls left) (See Figure 1-3).

As shown in Figure 1-3(A), the prosodic pattern for the utterance was constructed by a grid that represents the utterance's overall stress and timing pattern. Following Selkirk (1984), Ferreira assigned the content words (e.g., girls, left) with three grid marks. However, the function word (e.g., the) contains one less or two grid marks. In addition to the metrical pattern for individual words, further, the prosodic structure of the entire sentence needs to be also considered for the connected speech's prosody generation. Based on the number(s) of prosodic constituent boundary (i.e., prosodic word, phonological phrase, intonational phrase, utterance) in the sentence's prosodic structure (Figure 1-3(B)), corresponding numbers of grid marks are added either vertically or horizontally. The vertically-added grid marks represent the stress pattern for the sentence, while the horizontally-added grid marks represent the rhythmic or

timing pattern for the sentence. Somewhat different from earlier models of prosody generation, Ferreira's proposal can be considered as a more comprehensive version of prosody generation, in which both stress and temporal pattern generation for connected speech are described. Another important point to be added in Ferreira's proposal is that prosodic structure, which is considered as an entity that is independent from syntactic structure (Ferreira, 1991, 1993), plays a role in prosody generation for connected speech.

Keating and Shattuck-Hufnagel (2002)'s Perspective

More recently, Keating & Shattuck-Hafnagel (2002) proposed a more radical prosodic perspective of speech production. Basically, they argued that some default prosodic structure should be constructed at the initial stage of speech production, which by a series of reconstructions, moves gradually closer to the surface form until some higher level of prosodic structure is constructed and finally made available to a speaker. Especially, they argued that the relatively well-defined prosodic structure will be available at least during the stage of the Prosodic Word encoding through which sound segments are properly ordered and adapted according to the prosodic context.

Basically, the researchers criticized Levelt's (1989) assumption of incrementalism, which suggests that each representation, from the lexical word to phonetic spell-out, is incrementally (i.e., frame-by-frame in a left-to-right fashion with no requirement of look-ahead) generated. The incrementalism model indicates that surface structure should be accessed in a basic form (or frame) of the Prosodic Word (i.e., a content word or its forms attached by any extra function word(s)) and it is therefore inconceivable that the surface structure can be accessed in some larger constituents than the Prosodic Word (Levelt, 1989).

Keating & Shattuck-Hafnagel (2002) presented some cases against the incrementalism. One such case relates to instances in which segmental movements occur across Prosodic Word

boundaries during speech errors (e.g., chee kain for key chain, dretter swying for sweater drying (Fromkin, 1971, Shattuck-Hufnagel, 1979, 1992)). Levelt (1989) explained this phenomenon by arguing that some speaking contexts may allow lookahead into the next Prosodic Word. However, Keating & Shattuck-Hafnagel (2002) presented some more challenging examples for the lookahead of stretching over more segments and boundaries (e.g., the Sicks and the kneltics for the Knicks and the Celtics). In order to explain those cases against the incrementalism, therefore, they argued that an even larger buffer than the Prosodic Word should be allowed to encompass a separate and distant phrasal boundary. During the Prosodic Word encoding, a higher level of prosodic structure for the surface form should be already available to a speaker. Based on this reasoning for speech generation model, Keating & Shattuck-Hufnagel termed their model as the "prosody-first, segments-later model" (p. 251). As Keating & Shattuck-Hafnagel pointed out (p. 251), however, the radical prosodic perspective of speech generation needs to account for the larger body of experimental or natural speech-related data in order to gain its further descriptive or explanatory adequacy.

Literature Review: Stuttering as a Prosody-Related Deficit

Correlation between Stuttering and Linguistic Stress

Stuttering and its association with prosody were first identified by uncovering significant correlations between the loci of stuttering events and linguistic stress. Using several passage reading tasks, Brown (1938) reported that persons who stutter produced more disfluencies, especially on stressed words. He interpreted the observation as a reflection of a speaker's awareness of psychologically prominent or communicatively important words. According to Brown, speakers who stutter tend to display oversensitivity to speech performance and become disfluent on words that typically bear the primary meaning load in sentences. Brown also noted

that some other linguistic factors (e.g., word position within a sentence, word length, grammatical class) increase the likelihood of stuttering to occur.

Wingate (1984, 1988) argued that most loci for stuttering events originally observed in the Brown's study, such as content (or lexical) words or relatively longer words, can be accounted for by the fact that they represent points of linguistic stress (i.e., function words typically receive weak stress or unstressed, but content words or longer words often bear primary or secondary stress). In addition, Wingate (1984) argued that there is a close relationship between the loci of stuttering and syllable stress peaks even in connected speech. Noting the tendency for stuttering to occur at word (or syllable) initial position, furthermore, he argued that people who stutter have difficulties in actualizing stress on the word (syllable) onset position. The basic assumption espoused by Wingate, therefore, can be that stuttering is a symptom of a prosodic disturbance or disorder.

Bergmann (1986) supported Wingate's interpretation and showed that stuttering events tend to occur more often on stressed words than they do on unstressed words, regardless of the location of the word in the utterance. Bergmann asked German participants who stutter to read aloud a set of sentences on cards (e.g., Herr Vogt putzt das Auto. (meaning Mister Vogt cleans the car)), while they responded to particular questions (e.g., Wer putzt das Auto? (meaning Who cleans the car?)) or Was macht Herr Vogt an seinem Auto?" (meaning What is Mister Vogt doing with the car?)). Anticipating that linguistic stress is placed differently according to the linguistic context, Bergmann investigated the ratio of stuttering frequency of the stressed words relative to those of non-stressed words. Consistent with Wingate's argument, a high ratio of stuttering frequency on the stressed words was found regardless of its location in the utterance. In addition, he found that persons who stutter speak more disfluently during a fable reading than

they do during the reading of a poem with regular meter. He interpreted the finding as a result of more burden imposed on the speakers who stutter in reading a fable with more variable patterns of accents. He concluded from the findings that stuttering is a prosodic disturbance or disorder.

Somewhat later, Klouda & Cooper (1988) investigated the relationship between stuttering and contrastive stress. As well studied (Atkinson, 1973; Brown & McGlone, 1974; Eady & Cooper, 1986; Eady & Mueller, 1985), contrastive stress is marked acoustically by longer duration, higher amplitude, and dramatic change in pitch. It can be reasonably predicted that because of a motor-related burden in producing contrastive stress, speakers who stutter tend to stutter most of the time on words that express contrastive stress. To test the hypothesis, Klouda and Cooper asked participants who stutter to read a set of sentences (e.g., Maryann picked the gift that Priscilla sent to her grandfather). In order for the subjects to be induced to place contrastive stress correctly on certain word (e.g., Maryann), Klouda and Cooper made up a set of questions (e.g., Did Maryann or Nancy pick the gift that Priscilla sent to her grandfather?). A statistical association between the application of contrastive stress and the increase in stuttering frequency was found. The researchers suggested that some type of motor-related burden, such as that associated with laryngeal and/or air pressure adjustments, leads the speakers who stutter to more disfluencies on words with contrastive stress.

As mentioned earlier, Wingate (1984) argued that there is a close relationship between the loci of stuttering and syllable stress peaks in connected speech. However, Prins, Hubbard, and Krause (1991) noted that the reliability of stutter event loci judgments in the earlier study was apparently established for words, but not for syllables. Prins et al. argued that the relationship between stuttering frequency and linguistic stress needs to be investigated in association with every syllable in connected speech, rather than every word in connected speech, as Wingate,

(1984) had done. Based on experts' judgments of stress, Prins et al. classified the level of stress for every syllable in connected speech (i.e., The Rainbow Passage) into one of the following two categories: peak (i.e., one syllable surrounded on each side by syllables of lesser stress), unstressed (i.e., one syllable surrounded on each side by syllables of greater stress), and other category of stress (i.e., not applicable in the first two categories) (See Figure 1-4 for illustration) and examined the occurrence of stuttering and its proportional distribution according to the level of syllabic stress for a syllable. Interestingly, they found that with exception of the first three words of principal clauses within a sentence, there was a stronger correlation between stuttering and stressed syllable peaks (r =.49) in comparison with that between stuttering and unstressed syllables (r =.25).

By applying the same syllable stress rating method as employed in the Prins, Hubbard, and Krause study (1991), Natke, Grosser, Sandrieser, and Kalveram (2002) extended Prins et al.'s work by adding the prosodic aspect of duration into consideration. Specifically, they investigated the relationship between stuttering on stressed syllables and the duration of those stressed syllables. Based on the incorporation of the two prosodic aspects (i.e., stress, duration), they classified each of syllables into further subgroups (i.e., long and short stress-peak syllable, unstressed syllable, intermediate syllable). In order to isolate effects of within-word position of stress on stuttering, they further examined the incidence of stuttering by classifying each of syllables as either "utterance-initial" or "subsequent" positions. The main finding in the study was that in subsequent positions, stressed syllables were more likely to be stuttered than unstressed syllables (24.3% vs. 3.5%), which was consistent with Prins et al. (1991). As with Prins et al., linguistic stress seemed to have less effect on the overt occurrence of stuttering behavior during utterance-initial contexts. In contrast, Natke et al. found no significant effect

upon stuttering for durational aspect. That is, it was found that shorter stressed syllables were just as likely to be disfluent as longer syllables in both the utterance initial position (35.2% vs. 32.6%) as well as in subsequent positions (28.7% vs. 20.1%).

As noted above, some studies (e.g., Prins et al., 1991; Natke et al., 2002) have used sentences or passages as the main stimuli for examining prosodic effects upon stuttering behaviors, and they have analyzed stuttering frequency in terms of its correlation with linguistic stress. One main weakness of those studies is that despite the usage of sentences or passages as main reading material, they do not consider or control for the effects of phrasal or sentential prosody, which usually govern such word-level factors as lexical stress (Arbisi-Kelm, 2006). Controlling for the effects of phrasal prosody, therefore, Arbisi-Kelm (2006) investigated the frequency of stuttering on pitch-accented words (i.e., more stressed and prominent words in the utterance). Arbisi-Kelm (2006) asked subjects who stutter to narrate a picture book (i.e., Frog, where are you? Mayer, 1969) as if they were sharing the story with someone for the first time. The resulting narrative samples were then analyzed. Arbisi-Kelm found that, for speakers who stutter, stutter-like disfluency was more often located on prominent words (i.e., pitch-accented and nuclear pitch accented words) than it was on non-prominent words (i.e., unaccented words). However, subjects with normal fluency (i.e., control subjects) showed a reversed tendency. That is, the controls produced more disfluencies on unaccented words than on accented words (57.2% vs. 42.8%, p =.0038). Arbisi-Kelm (2006) argued that there is a close correlation between stuttering and the level of linguistic stress, and that stuttering is likely to be a manifestation of prosodic disturbance or deficit.

It should be noted, however, that there are some “contradictory” studies, which have shown a stronger effect for word position (more specifically, word-initial position) than for

linguistic stress on stuttering behavior (e.g., Hubbard, 1998; Weiner, 1984). In Weiner's (1984) study, for example, the stimuli consisted of sentences that contained particular words whose stress pattern was determined by the context (e.g., Give me your address vs. Address the crowd). Weiner found that regardless of the locations of syllabic stress for the underlined words, stuttering occurred predominantly on the syllables at the word-initial position (e.g., ad-, Ad-). As seen in the examples, however, the main weakness of the Weiner's study is that it did not control the position of the word in the utterances (Hubbard, 1998).

Hubbard (1998) also found that word position had a greater effect on the occurrence of stuttering than syllabic stress did. Using two-syllable target words that were embedded within sentences (e.g., Senate reports concern dollars that help vs. Secret reasons comfort dollars that help), Hubbard demonstrated that stuttering consistently occurred on the word initial syllables (e.g., re-, con-, rea-, com-) regardless of the location of syllabic stress. However, Hubbard also provided some other possible explanations on the findings. Firstly, she pointed out that the disyllabic words used in her study may represent a special case that mask the tendency for stuttering to occur on stressed syllables. For example, the syntax of the stimulus sentences rendered what might be termed a "newspaper title". In her study, word onset also was confounded with the onset of larger structures such as intermediate phrases and phonological phrases, and that when viewed from this perspective, the results of her study may actually be consistent with a prosodic interpretation.

Prosodic Factors in Prominent Theories of Stuttering

As noted earlier in this chapter, prosodic factors have been integral to several prominent theories of stuttering. In this section, we will briefly review several such theories.

Kent's perspective (1984)

Kent (1984) argued that stuttering is fundamentally a temporal programming disorder and he hypothesized that individuals who stutter are not able to properly generate the temporal programs and/or or time structures for action that underlie fluent speech production. Noting the disassociation between segmental and prosodic information during speech production (Fromkin, 1971; Garrett, 1975; Shattuck-Hufnagel, 1979; Stemberger, 1985), Kent argued that speech production requires speakers to synchronously integrate segmental (linguistic) and paralinguistic (prosodic) information. For the successful integration of the two independent components during the speech production, Kent proposed the existence of a central processor, which acts to integrate the two different lines of temporal processing. Kent supported his hypothesis using evidence of timing breakdown in the speech of persons who stutter from several studies (e.g., Cooper & Allen, 1977; Ibbotson & Morton, 1981; Sussman, 1982). He argued that speakers who stutter are less capable of generating or maintaining properly the temporal structure for action of speech because of their critical deficit in the central processor.

Neuropsycholinguistic model (Perkins, Kent, & Curlee, 1991)

Several years later, Kent's (1984) prosody integration deficit hypothesis was expanded into a more comprehensive model, namely, the neuropsycholinguistic theory of stuttering (Perkins, Kent, & Curlee, 1991). The authors hypothesized that stuttering mainly involves a breakdown in the integration or alignment of segmental and prosodic information prior to speech initiation. As shown in Figure 1-5, the neuropsycholinguistic model of stuttering assumed that for the successful generation of speech, a number of systems are required to function in an orderly, coordinated fashion. More specifically, such autonomous and independent processing systems as the cognitive system, language system, and paralinguistic-prosodic system (or PP system) must be tightly synchronized for the generation of fluent speech to occur

According to the model, two main types of disfluencies (i.e., normal disfluencies, stuttered disfluencies) occur when the PP system and segmental system are dyssynchronous. According to the model, stuttered disfluencies occur when the speaker's prosodic frame and associated segmental components are dyssynchronous and, at the same time, the speaker perceives excessive time pressure (i.e., the speaker's need to begin, continue, or accelerate an utterance). In contrast, normal disfluencies occur when the two systems are dyssynchronous but the speaker does not perceive excess time pressure. Even though this model of stuttering was based on a variety of theoretical assumptions or perspectives from speech and language pathology, psycholinguistics, cognitive science, and neuroscience, it has been pointed out that no reliable evidence to support the model has been presented (Bernstein Ratner, 1997).

Variability model (Packman, Onslow, & Menzies, 2000)

Noting a close relationship between prosody and fluency enhancing conditions such as rhythmic speech (Brady & Brady, 1972; Mallard, 1977; Silverman, 1976b), prolonged speech (Boberg, 1976; Evesham & Fransella, 1985; Howie et al., 1981), and syllable-timed speech (Andrew & Harris, 1964; Helps & Dalton, 1979), several Australian researchers (Packman, Code, & Onslow, 2007; Packman, Onslow, & Menzies, 2000; Packman, Onslow, Richard, & Doorn, 1996) have proposed that a change in prosody, in particular, changes in syllabic stress, is a critical feature of the fluency enhancing conditions. More specifically, the researchers have argued that the reason that speakers talk more fluently in conditions such as syllable-timed speech and prolonged speech is that in each of these conditions, speakers essentially reduce the variability of syllabic stress, as is manifested in the vowel duration of composite syllables. Packman and colleagues presented a theory of stuttering, which they termed "the Variability model" (or Vmodel). According to this model, people who stutter are presumed to have an underlying deficit in the speech production system which creates instability when individual is

called upon to produce sequential movements such as the syllables that comprise connected speech. According to their model, one of major sources of the perturbation that can lead to stuttering is the variability of syllabic stress, which is manifested mainly by changes in vowel duration across syllables. (See Figure 1-6 for illustration of the Variability model).

The Onset of Stuttering: Considering Prosodic Development in Children

The association of prosodic factors with stuttering can be also discussed under the consideration of the onset of stuttering. Many researchers (e.g., Bernstein Ratner, 1997) have argued that the onset of stuttering can be explained in association with aspects of language development. In particular, some have argued that the onset of stuttering is closely related to prosodic development in children (Allen & Hawkins, 1980; Karniol, 1995; Packman, Code, & Onslow, 2007; Wingate, 1967, 1988). It has been known that children during the preschool years typically experience a transitional period of language development wherein they evolve from using utterances that consist of either isolated words or simple word pairs, into utterances that more closely resemble complex sentences (Elbers & Wijnan, 1993; Locke, 1993; Radford, 1995; Wijnan, 1990). From a perspective of prosodic development in children, children who are at this stage of language development must also begin to implement complex prosodic rhythms which spread across these words boundaries, rather than the simple “syllable-timed” prosody that mainly characterizes their single word utterances (Allen & Hawkins, 1980). In this view, the need to produce utterances which feature these variable and complex prosodic patterns or rhythms might be a challenge to even to normally developing children, but they are especially troublesome for children who are predisposed to stutter (Allen & Hawkins, 1980; Wingate, 1967, 1988).

Stuttering and Fluency Enhancing Conditions

In some speaking conditions, people who stutter are not disfluent but rather speak as fluently or almost as fluently as normal speakers do. These speaking conditions have been termed "fluency enhancing conditions" (Andrew et al., 1982; Packman, Code, & Onslow, 2007). Examples of fluency enhancing conditions include the following: (1) rhythmic speech, (2) syllable-timed speech, (3) choral speech, (4) speaking while receiving delayed auditory feedback (DAF), and (5) speaking while receiving frequency-altered (auditory) feedback (FAF). A comprehensive review of stuttering during choral reading, DAF, and FAF will be presented below, as these are the fluency enhancing conditions which will be primarily dealt with in the present study.

Stuttering under Choral Speech

As implied by the term, choral reading is a situation in which one person is speaking along or simultaneously with one or more other speaker. It has been consistently demonstrated that stuttering is significantly reduced during choral reading (Andrews et al., 1982; Barber, 1939; Bloodstein, 1950; Freeman & Armson, 1998; Ingham & Packman, 1979; Ingham et al. 2006; Johnson & Rosen, 1937; Rami, 2000, 2005; Saltuklaroglu et al., 2006). The effects of choral reading on the frequency of stuttering were firstly noted experimentally by Johnson and Rosen (1937) and Barber (1939). Barber reported that stuttering essentially disappeared during the choral reading contexts, with the range of improvement noted to be on the order of 91% to 98%. Barber attributed the fluency enhancing effects to psychological mechanisms, namely "distraction". According to her, choral reading was a novel condition, and any such condition would distract speakers who stutter from their symptoms and allow them to talk with less self-perceived speech effort. The distraction effect hypothesis has been called into question by a number of researchers (e.g., Fransella, 1967; Fransella & Beech, 1969; Stuart, 1999; Wingate,

1969) as being overly vague and hard to empirically verify. In addition, there are findings from a number of studies that would argue against “distraction” as viable explanation for the distraction effect (Arends, Povel, & Kolk, 1988; Fransella & Beech, 1965; Mallard & Webb, 1980; Stuart, 1999). So, overall, the reasons underlying fluency enhancement remain poorly understood, but whatever the reason is, it seems to be something more than simple “distraction” (Wingate, 1968; Bloodstein & Bernstein Ratner, 2006).

It has been also reported that speakers who stutter are almost perfectly fluent during choral reading (Andrews et al., 1982; Bloodstein, 1950). In one of the first large-scale studies of fluency enhancing conditions, Bloodstein (1950) collected self-reported data through a survey of 204 people who stutter. The survey featured a list of 115 conditions that had the potential to induce fluency. Of the 115 conditions, choral reading was selected most often by the participants (i.e., 86% of the participants reported no stuttering at all in the choral reading condition). Similarly, Andrews et al. (1982) reported perfect fluency for adults who stutter (i.e., a 100% reduction in stuttering symptoms) under the choral reading condition.

Other researchers have examined other speech-related variables, including speech naturalness or speech rate in association with the choral reading. For example, Ingham & Packman (1979) investigated possible changes in speech quality (i.e., naturalness) as a result of the choral reading. They collected pairs of speech samples from oral reading that was produced under choral and non-choral conditions by four subjects who stutter. Then, the speech samples were presented to speakers with normal fluency and they were asked to judge if the two speech samples were from same or from different speaking conditions (i.e., choral or non-choral). The results suggested that that some of the subjects change their way of speaking in the choral reading condition and the listeners were able to perceive it. Interestingly, however, no significant

change in reading rate (speed) was found during the choral reading condition. Freeman and Armson (1998) reported somewhat different results than Ingham and Packman, finding that speech rate was increased during the choral reading condition. As some researchers have pointed out (Andrews et al., 1983; Kalinowski et al., 1993), however, an increased speech rate might be expected to impact speech fluency adversely in people who stutter. Ingham et al. (2006) addressed this by proposing that that choral reading may reduce self-perceived speech effort among speakers who stutter, which results in the ability to speak at what is, for them, a faster than normal rate.

Despite the consistent findings on the fluency enhancing effects of choral reading condition, it can be pointed out that no clear-cut explanation about the mechanism underlying the choral reading condition has provided (Bloodstein & Bernstein Ratner, 2006). Eisenson and Well (1942) observed a tendency for stuttering to increase in a choral reading situation wherein speakers who stutter read into a microphone and were told that they would be heard individually by an audience in another room. Consequently, Eisenson and Well argued that the fluency enhancing effects of choral reading are a reflection of the reduced communicative responsibility that people who stutter have in the situation. Pattie and Knight (1944) demonstrated that the choral speech signal was still effective when it was conveyed by telephone, which, according to the researchers, can be a situation where the speakers assume single responsibility for communication. Other researchers (e.g., Kent, 1984, Van Riper, 1982) have hypothesized that careful monitoring of another person's speech makes it possible for speakers who stutter to generate the temporal patterns that are necessary for fluent speech. This hypothesis remains largely untested. Using Baken's (1987) frequency-filtering technique, Rami (2000, 2005) manipulated the choral speech signal itself to investigate which component(s) of the choral

speech signal are associated with the fluency enhancing properties observed during choral reading condition. Rami created different versions of a choral speech signal (i.e., choral signal filtered at 100 Hz, choral signal filtered at 500 Hz, choral signal filtered at 1000 Hz, whispered choral speech, typical choral speech) according to frequency-filtering levels. Participants who stutter then read several printed passages while being exposed to various choral signals.

Results from the experiment showed marked reduction of stuttering during typical choral speech, choral speech filtered at 500 Hz, choral speech filtered at 1000 Hz, and whispered choral speech. In contrast, the participants showed essentially no reduction in stuttering under solo reading condition (i.e., normal auditory feedback (NAF)) or choral speech that was filtered at 100 Hz. Based on the findings, Rami proposed that acoustic cues pertaining to articulatory events that are encoded in the vocal tract are necessary for enhancing fluency during choral reading.

Saltuklaroglu, Kalinowski, and Guntupalli (2000, 2004) proposed that the choral speech signals activate the speaker's "mirror neuron system" (e.g., Rizzolatti et al., 1988). In this view, the accompanying choral speech signal provides speakers who stutter with cues about the articulatory gestures that are necessary to produce effortful, fluent speech. Basically, they argued that fluency enhancing effects observed during choral speech cannot be accounted for either by segmental cues or by prosodic cues of another speaker's voice. Rather, they proposed that some articulatory gestures (i.e., the co-articulated dynamic trajectories of the human vocal tract) are sufficient to enhance fluency during choral speech. Following the Revised Motor Theory of Speech Perception (Liberman & Mattingly, 1985; Liberman & Whalen, 2000), they assumed that articulatory gestures are invariant objects of both speech perception and production and speech perception and production mainly concerns encoding or decoding the same or shared articulatory gestures. Saltuklaroglu et al. argued that another speaker's voice would provide "an external

matrix of speech gestures that is rich in redundant speech cues" (p. 342) and a particular gestural cue (e.g., place of articulation, voicing, manner of articulation) in the external choral speech can be matched to one of cues found in the intended speech. The matching or imitation of articulatory gestures is the main key in explaining the reduction of stuttering during choral speech. According to them, furthermore, the imitation of articulatory gestures can be accomplished by an innate human capacity that is basically mediated by the mirror neuronal system (e.g., Rizzolatti et al., 1988). Since the fluency enhancing effect was still observed even when choral speech is just provided visually (i.e., silent speech) (Kalinowski et al., 2000), they argued that articulatory gestures are the only usable concept for explaining the mechanism underlying fluency enhancing effect observed under choral speech.

Stuttering under DAF and FAF

Speakers who stutter have also been found to speak more fluently when they are exposed to delayed auditory feedback (DAF) and/or frequency altered feedback (FAF) as they speak (Armson & Stuart, 1998; Goldimond, 1965; Guntupalli et al., 2005; Ingham et al., 1997; Kalinowski et al., 1993, 2002, 2004; Stuart et al., 1997, 2004, 2006; Lincoln et al., 2006; Stuart & Kalinowski, 2004; Van Borsel et al., 2003). As suggested by its name, DAF involves delaying the delivery of a speaker's own voice back to the speaker's ears, thereby creating a temporal mismatch between the time at which a person speaks and the time at which the person hears what he or she has spoken (Lee, 1950). Alternately, FAF involves shifting the frequency components within the playback of a speaker's voice down or up (e.g., - 0.5 octaves, +1.0 octave). In this condition, a speaker will hear his or her voice in essentially real-time, but the pitch of his or her voice will differ from how it typically is (Howell et al. 1987).

Even though the effectiveness of DAF and FAF has been well documented and some portable devices have been developed for use in everyday speaking situations (Block, Ingham, &

Bench, 1996; Ingham et al., 1997; Lincoln et al., 2006; Sparks et al., 2002; Stuart et al., 2004, 2006), the mechanisms underlying DAF or FAF for the fluency enhancing effect have not been identified to date. Several hypotheses about how DAF and FAF enhance fluency have been presented, however. Older views tend to characterize altered auditory feedback as a means of distracting the speaker who stutters from their concerns about speech production (Barber, 1939, 1940; Bloodstein, 1995, 1999; Jonhson & Rosen, 1937). Others have speculated that altered auditory feedback helps speakers who stutter to circumvent a malfunction or deficit in the auditory system (Stromsta, 1957; Webster & Lubker, 1968). Still others have hypothesized that DAF and FAF prod people who stutter into modifying movement patterns in the vocal tract musculature, and these modifications are sufficient to allow for the execution or relatively smooth, fluent speech (Perkins, 1979; Wingate, 1969, 1976, 1979).

An example of the latter hypothesis come from Wingate (1979) who argued that stuttering is reduced in the altered feedback condition because speakers who stutter are induced to emphasize phonation and continuity of phonation. This has the effect of altering prosody and, in particular, slows speech rate. Thus, Wingate essentially thought of the fluency enhancing effects of DAF as resulting from extended syllable duration (p. 237). Wingate (1984) argued that prosodic alterations play a role in all of the mainstream stuttering treatments, and that understanding the physiology of prosody would greatly enhance the understanding of stuttering.

Wingate's (1979) claim that increases in vowel duration underlie the fluency improvements seen in DAF was challenged by Kalinowski et al. (1993), who showed that slowed speech rate is not necessary for enhancing fluency either during DAF or during FAF and the fluency enhancing effect can be observed during relatively fast reading. Specifically, Kalinowski et al. asked subjects who stutter to read printed passages either at their normal rate or at a fast

rate. Reading was done under several different feedback conditions (i.e., non-altered feedback (NAF), DAF, FAF, and masking). Regardless of the subject's reading rate, the fluency enhancing effects were observed under DAF and FAF. This led the authors to conclude that a slowed speech rate is not necessary for fluency inducement under DAF and FAF and therefore, a strict form of Wingate's vocalization hypothesis is not true.

Instead, Kalinowski et al. (1993) explained the fluency enhancing effects of DAF and FAF as a manifestation of the "double speaker phenomenon" (p. 12), which simply states that stuttering is reduced significantly in any context in which a speaker who stutter talks along with second speech signal. Kalinowski et al. proposed that speakers who stutter treat DAF and FAF as electronic forms of the double (or second) speaker phenomenon, because the acoustic signals associated with their own voice are received in a way that is different from normal. In essence, they considered FAF as another form of choral (or unison) speech, with additional view of DAF as a form of "shadow speech" in which another speaker's voice is slightly delayed relative to the speakers' original speech. However, Kalinowski et al. did not provide a more detailed explanation of the specific mechanisms that would underlie the double speaker phenomenon.

A number of studies have examined where, within DAF and FAF, maximum fluency enhancement occurs (Bloodstein & Bernstein Ratner, 2006). Noting the correlation between stuttering rate and a degree to which auditory feedback is delayed, Lincoln et al. (2006) reported that maximum fluency enhancement occurs in the range of 50 to 75 msec. with a 50 msec. delay being the best choice for obtaining maximum fluency improvement. In FAF, on the other hand, one-quarter to one full octave shift up or down appeared to generate maximal fluency (Hargrave et al., 1994; Lincoln et al., 2006; Stuart et al., 1996).

Rationale for the Present Study

As discussed earlier, many studies have linked prosodic factors to stuttering. For example, it has been shown that stuttering tends to occur more often on words that bear lexical or phrasal stress than words that do not (Arbisi-Kelm, 2006; Bergmann, 1986; Brown, 1938; Klouda & Cooper, 1988; Natke et al., 2002; Prins, Hubbard, & Krause, 1991; Wingate, 1984). Moreover, prosodic factors have been featured prominently in several theories of stuttering (Kent, 1984; MacKay, 1987; MacKay & Kent, 1986; Perkins, Kent, & Curlee, 1991; Packman, Onslow, & Menzies, 2000). The exact role of prosody in the speech fluency of speakers who stutter, however, remains unclear. The present study is mainly aimed at investigating role of prosody in stutterers' speech fluency. More specifically, this study examined the role of prosody in the fluency enhancing effect that is observed during the choral reading condition. As mentioned earlier, it has been well demonstrated that people who stutter exhibit marked improvements in fluency when speaking chorally with other(s) (Andrews et al., 1982; Barber, 1939; Bloodstein, 1950; Freeman & Armson, 1998; Ingham & Packman, 1979; Ingham et al. 2006; Rami, 2000, 2005; Saltuklaroglu et al., 2006). However, it can be pointed out that there is no clear-cut explanation about the mechanism underlying the choral feedback condition through which the frequency of stuttering is dramatically reduced. Some researchers (e.g., Alm, 2004; Kent, 1984) have proposed that careful monitoring of another person's speech makes it possible for speakers who stutter to generate the temporal patterns that are necessary for fluent speech. But it can be argued that this explanation is not a fact but simply a hypothesis to be tested.

Using acoustic filtering of the choral speech signal itself, Rami (2000, 2005) suggested that exposure to articulatory events which are encoded in the vocal tract is necessary for the fluency enhancement that is observed during the choral reading condition. Basically, Rami implied that neither segmental cues (e.g. segment sounds) nor prosodic cues alone (e.g., intonation, temporal

pattern) play a role in triggering fluent speech under the choral reading condition. However, it is not possible to know clearly whether fluency enhancing effects of choral speech result from segmental cues or prosodic cues in the sense that segmental and prosodic signals are largely confounded in the choral feedback signal and because facilitation of speech fluency with people who stutter has also been demonstrated through provision of simple rhythmic stimulation (e.g., metronome effect). Thus, the purpose of the present study is to examine the effect that manipulation of prosodic signals within the choral feedback signal (i.e., durational pattern, intonation) has upon speech fluency in choral reading conditions. Such an approach will allow us to answer what we feel is central question to understanding the role of prosodic mechanisms in speech fluency, that is: "Is the fluency enhancing effect observed in choral auditory feedback conditions where prosodic information is significantly altered, but segmental information is not?"

As discussed earlier in this chapter, it has been shown that stuttering is remarkably reduced in DAF and FAF. Thus, it can be noted that some alterations either in temporal structure (as in DAF) or in frequency (as in FAF) yield similar fluency enhancement effects. However, there have been few studies on prosodic alterations and their effect on fluency under the choral reading condition in which speakers receive other speaker's voice feedback. Furthermore, it can be pointed out that in DAF, FAF, and choral reading conditions, the prosodic cues mainly associated with word durational pattern and intonation (pitch contour) are provided to the speakers with them essentially intact. Therefore, the extent to which fluency enhancement in the above conditions is facilitated by prosodic cues is unclear. One way to study the role of prosody in stuttered speech would be to manipulate prosodic information within these fluency enhancing conditions (i.e., manipulating temporal information, manipulating pitch information, obscuring

prosodic cues (i.e., multi-speaker babble noise)). By manipulating prosodic information of choral feedback signal, the present study is aimed to examine whether fluency enhancing effect can be still observed even when prosodic information of choral feedback signal is significantly manipulated.

Furthermore, as mentioned above, Kent (1984) proposed that careful monitoring of another person's speech makes it possible for speakers who stutter to generate the temporal patterns that are necessary for fluent speech. Kent argued that the mechanisms underlying choral speech are similar to those observed in "the metronome effect" (i.e., fluency inducement in response to an external rhythmic signal). According to Kent, speakers who stutter use the other speaker's voice as an external signal which provides an external timing (or rhythmic) pattern that the speaker then utilizes to extract temporal information about ongoing speech. If speakers who stutter use the choral speech and benefit from it for their fluency improvement, one of plausible assumptions to be made can be that speakers who stutter show more entrainment to the choral speech than speakers who do not stutter do. Based on this rationale, the present study also examined if there were significant differences in the entrainment (i.e., the extent to which the speaker's fluent responses are entrained with choral model speech) of speakers who stutter and speakers who do not stutter.

Purpose of Study, Questions, and Hypotheses

The main purpose of this study is to investigate the role of prosody in the fluency enhancing properties associated with choral auditory feedback.

Question One

Do alterations in the availability and accuracy of prosodic information affect the extent to which choral auditory feedback enhances fluency?

Question Two

Do alterations in duration-based prosodic feedback affect speech fluency differently than alterations in pitch-based prosodic feedback do?

Question Three

Do participants who stutter benefit more from choral signals than participants with typical fluency do?

Question Four

Do participants who stutter speak as fluently when speaking under prosody altered choral feedback as when speaking under DAF, FAF, and typical choral reading conditions?

Hypothesis One

Participants who stutter will speak less fluently under prosody altered choral feedback than under typical choral feedback.

Hypothesis Two

Participants with typical fluency (i.e., non-stuttering group) will be less affected by prosody altered choral feedback than participants who stutter.

Hypothesis Three

Temporal manipulation of auditory choral models will affect fluency more than pitch-based manipulations will.

Hypothesis Four

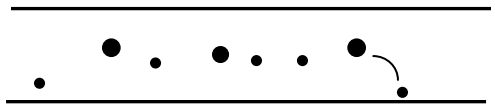
Participants who stutter will benefit more from choral signals and show more entrainment to the choral model.

Hypothesis Five

Participants who stutter will speak less fluently under prosody altered choral feedback than when speaking under DAF, FAF, and typical choral reading conditions.

```
                          *      nuclear pitch accent
                          *      pitch accent
   *     *                *      content word vs. function word
         *       *        *      lexically-stressed syllable
 *       * *     *  *    * *  *  syllable
(She's)(leaving) (Boston) (tomorrow)
```

A



B

She's leaving Boston tomorrow

Figure 1-1. Two types of transcriptions of stress patterns of She's leaving Boston tomorrow (A) The grid-marked stress pattern of She's leaving Boston tomorrow (B) The dot-marked stress pattern of She's leaving Boston tomorrow (adapted from Warren, 2000)

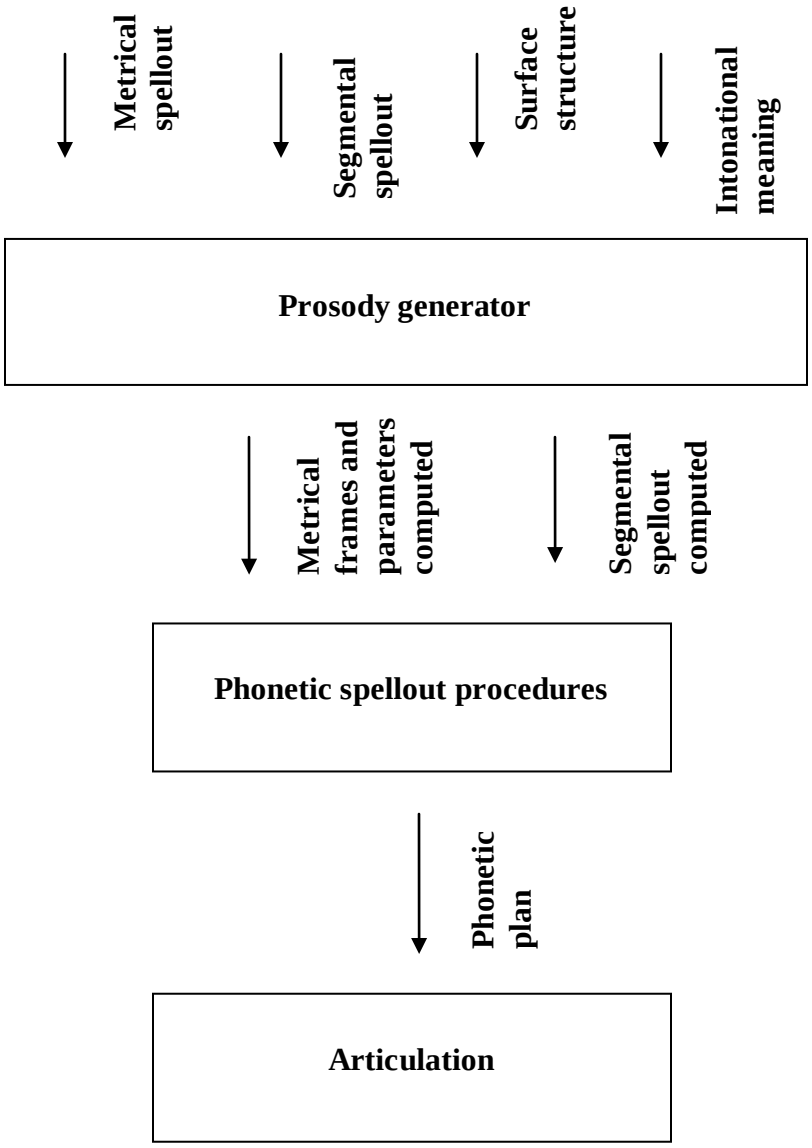
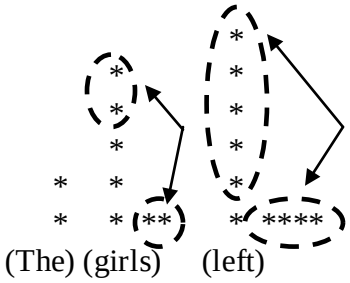


Figure 1-2. The phonological encoding of connected utterance (adapted from Levelt's (1989) speech production and phonological encoding model)



A

[(The girls)]PWd]PPh(left)PWd]PPh]IPh]Utt B
(PWd = Prosodic word; PPh = Phonological phrase; IPh = Intonational phrase; Utt = utterance)

Figure 1-3. Prosodic generation of The girls left (A) Stress and timing pattern of The girls left (B) The prosodic structure of The girls left (adapted from Ferreira, 1993)

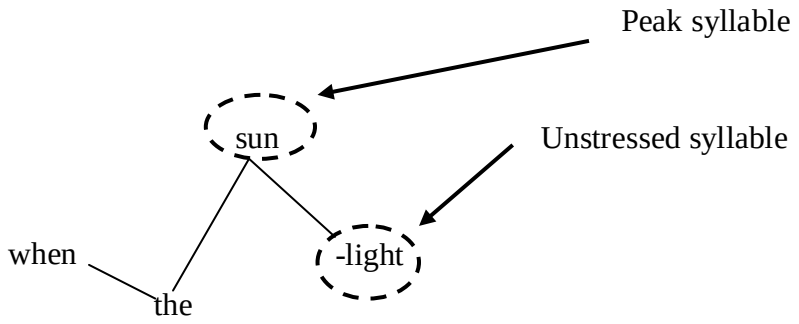


Figure 1-4. Prototypic syllabic stress pattern (adapted from Prins et al., 1993)

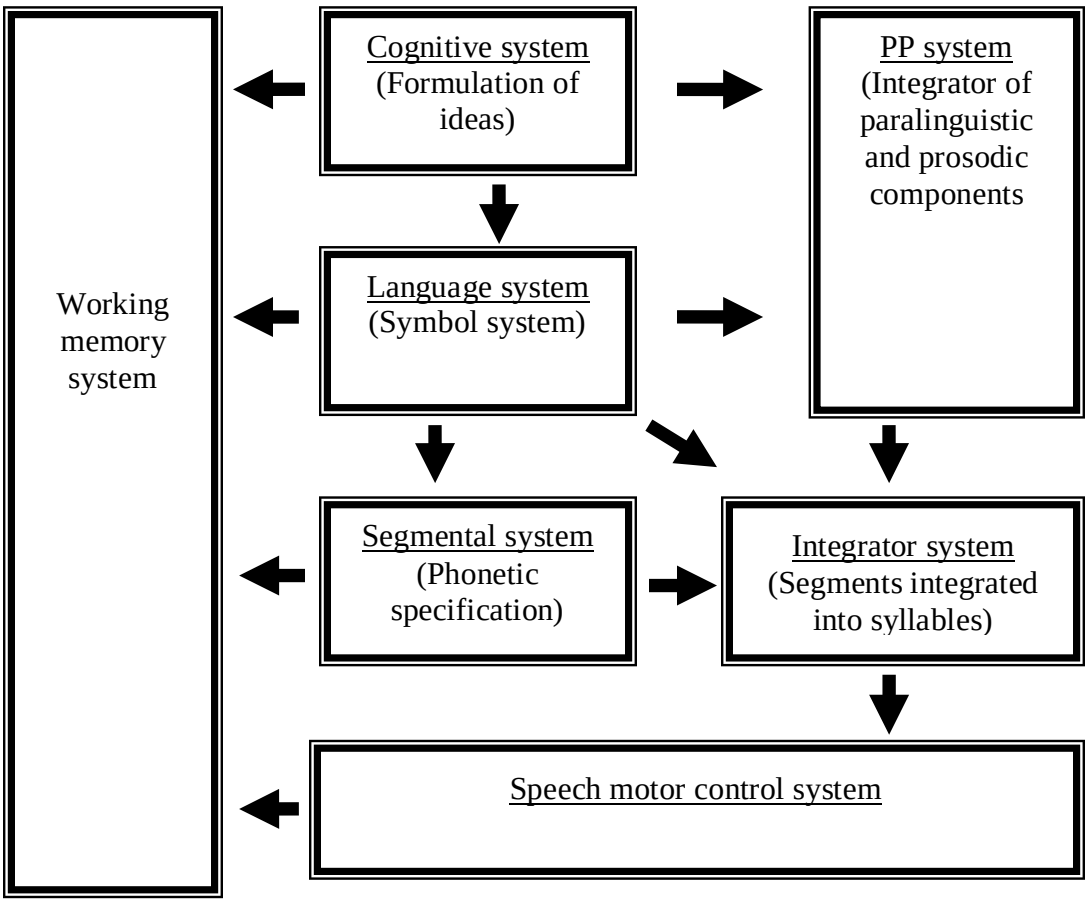


Figure 1-5. A model of neuropsycholinguistic systems required for disfluencies (adapted from Perkins, Kent, & Curlee, 1991)

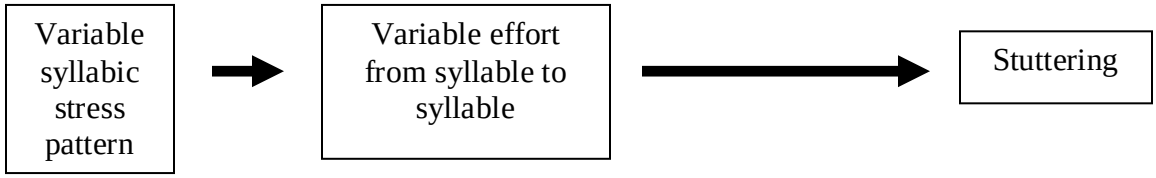


Figure 1-6. The Variability model (adapted from Packman, Onslow, & Menzies, 2000)

CHAPTER 2
METHOD

Participants

8 speakers who stutter and 8 speakers who do not stutter participated in this study. Participants in both groups were matched for age (experimental (stuttering) group: Mean = 22 years, SD. = 12.27 years, Range = 19-62; control (non-stuttering) group: Mean = 23 years, SD. = 13.75, years Range=18-23) and gender (6 of 8 pairs were matched for gender and age). The participants were recruited by contacting patients on the waiting list for diagnostic evaluations at the University of Florida Speech and Clinic, by posting signs at University-affiliated speech and hearing clinics in the State of Florida, by posting notices on the University of Florida campus, and by announcing the study in various classes at the University of Florida. Participants were included on a basis of the following criteria:

Be adults who are at least 18 years of age

Speak American English with native competency

Have a negative history of any medical, emotional, or neurological (other than stuttering), conditions that might influence their speech fluency performance during the study

Obtain a standard score of 85 or above on the Peabody Vocabulary Test-3rd Edition (PPVT-III; Dunn & Dunn, 1997)

Have no known or reported reading, language, or learning disabilities

Pass an oral reading screening

Have neither self-reported hearing nor vision-related problems

Additional criterion for inclusion in the experimental group (i.e., stuttering group) included the following:

No speech or language disorders, other than stuttering,

No recent history (i.e. within two years) of extensive altered auditory feedback-based treatment

The participants' demographic and test performance information is summarized in Table 2-1.

Procedures

Preliminary Information

Each of the participants was seen, individually, for two sessions. During the first session, participants provided background information by completing a questionnaire that included a variety of questions relating to age, educational level, medical and educational histories, and for stuttering participants, time of stuttering onset, history of stuttering in family, characteristics of stuttering and related symptoms, and effects of stuttering upon quality of life (See Appendix A). Background information of participants who stutter, especially, relating to their symptoms of stuttering, is presented in Table 2-2. Participants also completed several formal tasks to verify their eligibility for the study. Those formal tasks included the following: (1) the Peabody Picture Vocabulary Test (PPVT-III, Dunn & Dunn, 1997), which was used to assess vocabulary comprehension ability, and (2) the Wide Range Achievement Test 3 (WRAT3, Jastak, 1984), which was used to evaluate participants' basic reading ability. These preliminary screening tasks took approximately 20 to 30 minutes to complete.

Baseline Speech Samples

In order to obtain baseline data related to speech fluency, a conversational speech sample was elicited from each of the participants. To do so, participants were asked to talk for at least 3 minutes on one or more of several topics (e.g., a recent movie or television program they had seen, the types of hobbies they have, things that they do on a typical week day, a favorite vacation). The baseline sample collection took approximately 10 minutes to complete.

Experimental Tasks

Upon successfully completing the preceding tasks, participants who met the inclusion criteria were invited to participate in the experimental task, in which participants were asked to read aloud a total of 420 sentences (i.e., 60 sentences in each of 7 auditory feedback conditions). Prior to commencing the experimental task, a research assistant briefly described the task to the participants, and presented several practice items to the participants to familiarize him/her with the task. The exact script that the assistant used during the experimental tasks is shown in Appendix B. After a participant successfully responded to the practice items, he or she was asked to read aloud the experimental sentences during each of several auditory feedback conditions.

As noted, the experiment was divided into blocks, each of which featured 60 sentences which were presented to participants under one of 7 auditory feedback conditions. The sentences ranged from 18 to 21 syllables in length, and were presented to participants individually on a computer screen. The seven conditions were as follows: (1) normal auditory feedback (NAF), (2) delayed auditory feedback (DAF), (3) frequency altered feedback (FAF), (4) choral reading with normal auditory feedback (CH-NAF), (5) choral reading with pitch-contour altered auditory feedback (CH-PAF), (6) choral reading with temporal-pattern altered auditory feedback (CH-TAF), and (7) choral reading with multi-speaker babble auditory feedback (CH-BAF). The experimental conditions are summarized in Table 2-3. Presentation order was randomized for the seven auditory feedback conditions across participants and data collection sessions.

Brief “distractor tasks” (e.g., oral readings of unrelated stimuli) were introduced at the conclusion of each block of sentences to minimize the carryover effects that might be observed between some blocks of the experimental conditions. The distractor tasks consisted of 6 short typed passages on different topics (i.e., sparrows, Valentine’s Day, spiders, hibernating animals, baseball, rainbows). Participants read one of the six passages following completion of a block of

the experimental tasks. The reading passages contained 255 words on average and were written at a middle school level. The reading passages were originally obtained from an internet-based educational website (www.abcteach.com) and were edited slightly by an English native speaker (Appendix C) to fit the specific length requirements desired for the present study. Data from the paragraph reading activities was also analyzed to monitor participants' fluency over the course of the experiment.

Materials

Sentence Stimuli

As mentioned above, 60 sentences were used as the main experimental stimuli. These consisted of 20 sentences which were matched for length, syntax, and semantics (or word frequency), and 40 other sentences that featured diverse syntactic and prosodic patterns. Overall, however, all experimental sentences were similar in length. The subset of 20 matched sentences ranged in length from 18 to 20 syllables and 10 words; and the other sentences ranged in length from 17 to 21 syllables and from 10 to 11 words. As shown in Appendix D, the 20 matched sentences (e.g., The policeman and detective had ticketed the Canadian by mistake) contained consistent NP and VP syntactic structure and prosodic pattern. In addition, phrase structures within the sentences were matched as well, with each consisting of one or more function words (i.e., The, and, had, by) followed by content words (i.e., policeman, detective, ticketed, Canadian, mistake). Thus, the general prosodic pattern within these sentences was consistent, with each sentence consisting of a series of prominent and longer content words which followed non-prominent and shorter function words. As shown in the appendix, each of the content words began with consonant and consisted of two syllables or more. Multi-syllable words have been shown to have a high probability of being stuttered in comparison with monosyllable words (Howell, Au-Yeung, & Sackin, 1999; Klouda & Cooper, 1988).

To minimize the potential for a carryover effect from the common syntactic and prosodic structure within the 20 matched sentences, 40 other sentences that featured diverse syntactic and prosodic patterns (e.g., The athlete who ran for student government selected his running mates) were created and incorporated with the pool of experimental stimuli (Appendix D). Content for the two types of sentences was derived from an English grammar book (Fundamentals of English Grammar, Azar, 1992) and then adapted by an American English speaking adult to make them similar in word length or frequency with each other. Some similarities and differences between the two types of sentences are summarized in Table 2-4.

Auditory Feedback Conditions

To create the different versions of the choral sentence stimuli, digital audio recordings of each of the sentences first were made by having a female American-English speaking adult with typical speech read the sentences aloud. Subsequently, the main investigator created prosody-altered versions of these sentences using a computer program (PRAAT; Boersma & Weenink, version 4.4.28), through which it is possible to modify aspects of prosody such as pitch contour and temporal patterning.

As indicated, two types of prosody-altered sentences were created: sentences which featured alterations of the pitch contour and sentences which featured alterations of temporal patterning. Specifically, the pitch contour altered versions of the sentences were less informative about pitch contour in terms of relative highness in tone (i.e., they featured a constant or flat pitch contour). In terms of manipulating durational pattern of speech signal, similarly, the prosody-altered versions of the sentences were less informative about temporal pattern in terms of relative word length (i.e., word duration was standardized).

The pitch contour altered versions of the sentences were created simply by reconfiguring the sentential pitch contour patterns for each of the experimental sentences to be constant or flat.

Frequency values of the first syllables of each of the experimental sentences were chosen as the point where to flatten the inflection. With respect to alteration of durational pattern, the concept of relative prominence was used. When several words are combined to form compounds or phrases, as discussed in the previous chapter, stress pattern is determined on a basis of relative prominence among words and it can be argued that the pitch accented word is considered as most prominent constituent in the multiword domain (Spencer, 1995). In the present study, therefore, word durational pattern was considered and manipulated.

In the 20 sentences, each of the temporally-altered versions was obtained by manipulating word durational pattern in such a way that every word contained in each of the sentences would be almost same in duration. As mentioned earlier, each of the 20 matched experimental sentences consisted of phrases in which one or more function words was followed by content words. The manipulation in word durational pattern for these sentences was done by a way of elongating function words (which tend to be relatively short) and at the same time, shortening the content words (which tend to be relatively long). The 40 other sentences were also modified in the same way: elongating shorter or function words but shortening longer or content words. The extent to which each word contained in each of the sentences was either elongated or shortened was determined by considering the average range of manipulation used in the 20 matched sentence counterparts (i.e., Mean of elongation: 24 ms., S.D.=[+,- 5 ms.]; Mean of shortening: 26 ms., S.D.=[+, - 6 ms.]). Accordingly, the word durational pattern for each of the prosody-altered sentence versions was mismatched relative to that of the original choral version. However, the overall duration of each of the prosody-altered versions of the experimental sentences was not manipulated. Thus, the overall duration of each of the prosody-altered sentence was similar to that of its original version. In addition, the prosodic manipulations did not affect the sentence's

overall intelligibility, which indicates that each of the prosody-manipulated versions of sentences remain fairly understandable. The investigator asked each of participants to report any discomfort that she or he might have during the main experiment, but no difficulty in hearing or understanding the prosody-altered versions of speech signal was reported. Spectrographic examples of the prosody-altered versions of the choral speech are represented in Figure 2-1 and Figure 2-2.

Setting and Apparatus

Participants were seated in a comfortable chair in front of a laptop computer (Dell, Inspiron 2200) in a quiet room. Then, the participants were asked to read individual sentences on the computer screen, while sometimes listening to auditory feedback of their own voice (i.e., NAF, DAF, FAF) and sometimes listening to auditory feedback of another speaker's voice (i.e., CH-NAF, CH-TAF, CH-PAF, CH-BAF). Participants heard all of the auditory feedback through earphones (Logitech Premium Notebook Headset) at a comfortable listening levels (i.e., less than 75 dB SPL, Ramig, 2000, 2005). All speech responses obtained from the participants were collected with a microphone (Shure, SM 48) placed approximately 20 cm from participants. The microphone output was fed and recorded into the audio deck recorder (Sony DTC-ZA5ES). A digital camera (Cannon, NTSC 2R65MC) was used for video recording. A backup audio recording was also made using a portable digital recorder (Sony, ICD-P320). Experimental settings were differentiated according to individualized characteristics of each of the experimental tasks as described below.

NAF: Participants were asked to read aloud each of the sentences on a computer screen, but they did not hear any other voice feedback or anything through earphones, except their own voice through the air. Participants wore headphones during this condition.

CH-NAF, CH-TAF, CH-PAF, CH-BAF: Participants were asked to read aloud sentences on a computer screen. While reading, they heard either another speaker's voice saying the

sentences in either an unaltered manner (i.e., CH-NAF) or in one of the prosody-altered versions of the sentences (i.e., CH-TAF, CH-PAF, CH-BAF).

DAF, FAF: Participants were asked to read aloud sentences on a computer screen. While reading, they heard their own voice either at 75 ms. delay (DAF) or at one octave up in frequency (FAF) (Lincoln, 2006). All speech responses from participants were collected by the microphone and recorded into the deck recorder. A portable DAF/FAF electronic device (Basic Fluency System, Casa Futura Technologies) was used in these conditions.

Data Analysis

Dependent Variables

There were three main categories of dependent variables in the present study. First, stuttering frequency was analyzed as one of main dependent variables. The main point of interest was to investigate if there was a significant difference in stuttering frequency across the experimental conditions. This analysis was conducted based on the computation of verbal stuttering behaviors that included part-word repetition, whole-word repetition, audible or inaudible prolongation (or block), phrasal repetition, and clustered disfluencies with repetition or prolongation. The computation of verbal stuttering behaviors was conducted in a following way: the number of stuttered syllables per sentence was tallied and then summed across all sentences within the task and divided by the total number of syllables produced during the task (excluding any stuttered syllables). Definitions and specific examples for the verbal stuttering behaviors are seen in Table 2-5. For the participants who stuttered, in addition, nonverbal behaviors that were judged to be symptomatic of stuttered speech for the participants who stuttered were also measured (Conture & Kelly, 1991). Those nonverbal behaviors included extraneous rhythmic movements of non-speech musculature, excessively tense non-speech movements, gaze aversion produced in conjunction with repeated or prolonged speech, and rapid, repeated eye blinking in conjunction with word initiation. For the participants who did not stutter, however, the analysis focused mainly on determining the frequency of stutter-like disfluency, that is, sound, syllable,

and word repetitions and prolongations in speech. This was because people who do not stutter rarely produce the nonverbal behaviors that are observed in stuttered speech, and that was the case in this study, as well.

Secondly, speech rate (i.e., mean number of syllables uttered per second) was also analyzed. One purpose of the speech rate analysis was to investigate if there was a significant difference in the speech rates of the participants across the speaking tasks. Rate was computed by summing the total number of syllables within entire stretches of each of the sentences within a block, and then dividing by the sum of the total number of seconds taken to produce each of sentences within the block. Syllables produced during disfluent stretches of speech were excluded from the syllable counts. The total elapsed time was then divided into the total number of syllables produced to yield the number of syllables per second for the block of sentences.

Lastly, the extent to which the speaker's fluent responses were entrained with choral model speech was examined as well. Specifically, the entrainment analysis was done by two separate but related analyses: 1) speech rate analysis and 2) reference-point entrainment analysis. Information from the speech rate analysis was used to determine the extent to which the speech rates of the participants matched those of choral speech model while the sentences were being read aloud. The reference-point entrainment analysis was done to examine the extent to which specific phones within the participants' fluent responses (e.g., sentence-initial phones, sentence-medial phones, sentence-final phones) were entrained with those within the choral models. In terms of sentence-medial phones, initial stop consonants of 3 different content words located sentence-medially were chosen. It has been well reported that stuttering tends to occur frequently in sentence or word-initial positions (Wingate, 1984) and adults who stutter are more likely to stutter on content words than on function words (Howell, Au-Young, & Sackin, 1999;

Dworzynski & Howell, 2004). Thus, it can be predicted that participants who stutter will show more entrainment to those particular sentence-initial or word-initial phones of the choral model if they use choral signals and benefit more from them than normal participants do.

The reference-point entrainment analysis was specifically done by comparing 5 distinct reference phones located at different locations (i.e., sentence-initial, 3 sentence-medial, sentence-final) within the participants' responses with those within the choral models. To do so, information about specific time for each of the reference phones within participants' responses and within the choral models were respectively measured and their differences in time were then calculated. Ultimately, the differences in time were analyzed to see if there was a significant group difference (stuttering group vs. non-stuttering group) in the extent to which participants' responses were temporally mapped on to the choral models. The entrainment analyses (i.e., speech rate entrainment and reference point entrainment) were conducted, by randomly selecting 10 out of the 60 experimental sentences (i.e., 5 matched and 5 unmatched sentences) for each of the 3 different choral conditions (i.e., CH-NAF, CH-PAF, CH-TAF). For the entrainment analysis, choral feedback or models and participants' audio-responses were separately fed and recorded into the deck recorder by the use of line-splitter. The reference-point entrainment analysis is represented in Figure 2-3.

Reading accuracy (i.e., error frequency in reading) as a speech production associated variable was also examined. During experiment, especially, some worksheets were used by the investigators for keeping an on-line record of fluency/disfluency, reading accuracy, and speech rate (i.e., faster or slower relative to choral models) (Appendix E).

Intra-and Inter-Judge Reliability

The intra- and inter-judge reliability of measurements on stuttering frequency was determined by re-measuring participants' responses in randomly selected 2 experimental

conditions (i.e., NAF, CH-BAF) for two participants who stutter and one participant who do not stutter. For the calculation of intra- and inter-judge reliability of measurement on stuttering frequency, basically, the number of stuttered syllables for each of the experimental sentences was re-measured, percentage of syllable stuttered for the sentences was re-computed, and the re-computed percentage values were then subtracted from the original values. A one sample t-test was used to determine if the mean difference value between the original and the re-computed values was significantly different from '0'. In addition, the Pearson *r* correlation test was also used to compare the results between examiners, and to test whether or not inter- and intra-judge reliability measures are acceptable.

Results of Inter- and Intra-Judge Reliability for Stuttering Frequency

Results of one sample t-test revealed that there was no significant difference in the mean intra-judge reliability difference values for stuttering frequency ($t = .476$; $df = 238$; $p = .641$), which indicates that the original measured values in stuttering frequency and the values recomputed by the main investigator were not different. No significant difference in the mean inter-judge reliability difference values was also found for stuttering frequency ($t = .088$; $df = 238$; $p = .930$). Further, strong positive Pearson *r* correlations were found in stuttering frequency for intra-judge reliability ($r = .804$; $p < .001$) and the inter-judge reliability ($r = .761$; $p < .001$).

Table 2-1. Participants' demographic and test scores information

ID #	Age	Gender	Years of Education	PPVT scores	WRAT (pass or not pass)	Stuttering Severity	Current Treatment (yes/no)
S01	21	M	14	121	Pass	Moderate	Yes
S02	23	M	15	110	Pass	Mild	No
S03	22	M	15	105	Pass	Moderate	No
S04	20	M	16	103	Pass	Moderate	No
S05	22	M	14	101	Pass	Mild	No
S06	62	F	18	100	Pass	Severe	No
S07	20	M	15	100	Pass	Mild	No
S08	32	M	18	100	Pass	Mild	No
NS01	20	M	14	104	Pass	N/A	N/A
NS02	22	M	14	120	Pass	N/A	N/A
NS03	23	M	16	103	Pass	N/A	N/A
NS04	20	F	15	105	Pass	N/A	N/A
NS05	20	F	14	103	Pass	N/A	N/A
NS06	18	F	15	102	Pass	N/A	N/A
NS07	20	M	15	104	Pass	N/A	N/A
NS08	18	M	14	105	Pass	N/A	N/A

PPVT = the Peabody Picture Vocabulary Test; WRAT = the Wide Range Achievement Test

Table 2-2. Background information of participants who stutter related to stuttering

ID #	Onset of stuttering < age 6 or age 6 to 12	Familial history? (yes/no)	Current reaction(s) to stuttering	"Situations" with greatest amount of stuttering	Areas of life stuttering interferes with most
S01	age 6 to 12	Yes	Disappointment Acceptance Anger Awareness	-Read out loud -Speak when tired or excited	-Daily life
S02	age 6 to 12	Yes	Acceptance Anxiety	-Use the telephone -Talk to strangers -Speak when excited	-Social relationship -Work performance
S03	< age 6	No	Awareness Anxiety	-Talk to strangers -Say name	-Social relationship
S04	< age 6	No	Frustration Anger Shame Anxiety Embarrassment	-Use unfamiliar words -Say name -Speak when excited	-Work performance
S05	< age 6	Yes	Awareness Indifference Frustration	-Say name -Speak when excited	-Daily life -Social relationship
S06	< age 6	Yes	Awareness	-Read out loud -Speak when excited	-Nothing particular
S07	< age 6	No	Embarrassment Frustration	-Talk to strangers -Speaks when tired or excited	-Social relationship
S08	< age 6	Yes	Awareness	-Public speaking	-Work performance

Table 2-3. The seven experimental conditions and their individual characteristics

Types of feedback	Experimental Conditions	Definition of conditions
Solo Reading (i.e., using own speech feedback)	NAF	Hear own voice unaltered
	DAF	Hear own voice through ear phones at 75 ms delay
	FAF	Hear own voice through ear phones at +1 octave in frequency
Choral Reading (i.e., using other speaker(s)' voice feedback)	CH-NAF	Hear another speaker's voice unaltered through ear phones
	CH-TAF	Hear through ear phones another speaker's voice whose temporal pattern is altered to increase duration of function words and decrease duration of content words
	CH-PAF	Hear through ear phones another speaker's voice whose pitch contour pattern (i.e., intonation) is altered so that pitch contour remains flat throughout the sentence
	CH-BAF	Hear multi-speaker babble noise through ear phones

Table 2-4. Similarities and differences between the two types of experimental sentences

	The 20 matched sentences	The 40 other sentences
Length	19 syllables and 10 words on average	19 syllables and 10 words on average
Syntactic structure	Consistent NP and VP structures NP VP NP  [The policeman and detective] [had ticketed the Canadian] [by mistake] NP VP NP  [The detective from Germany][is searching for someone] [from Columbia]	Diverse syntactic structures
Prosodic pattern	Consistent stress and word durational pattern The [policeman] and [detective] had [ticketed] the [Canadian] by [mistake]. The [detective] from [Germany] is [searching] for [someone] from [Columbia]. (Words in bracket = stressed and longer words)	Diverse stress and word durational patterns

Table 2-5. Definitions and examples of the verbal stuttering behaviors

Types	Definitions	Examples
Part-word repetition (or PWR)	Instances in which the participants repeat a sound or syllable in a given word	The [puh-]policeman
Whole-word repetition (or WWR)	Instances in which the participants repeat either a one-syllable or multi-syllable word	[The-the]The policeman
Inaudible prolongation (i.e., blocks or breaks)	Instances in which the participants inaudibly seem to experience blocks or difficulties moving from a sound of a word to the next sound	The p----oliceman
Audible sound prolongation	Instances in which the participants prolong (audibly) a sound in a word for an abnormally long amount of time	The [pppp]policeman
Phrasal repetition	Instances in which the participants repeat phrase(s) within a sentence	[The policeman]The policeman
Cluster with repetitions and/or prolongations	Instances in which the participants consecutively produce multiple forms of repeated and/or prolonged speech prior to or during a word	The[ppp-p-pp] policeman

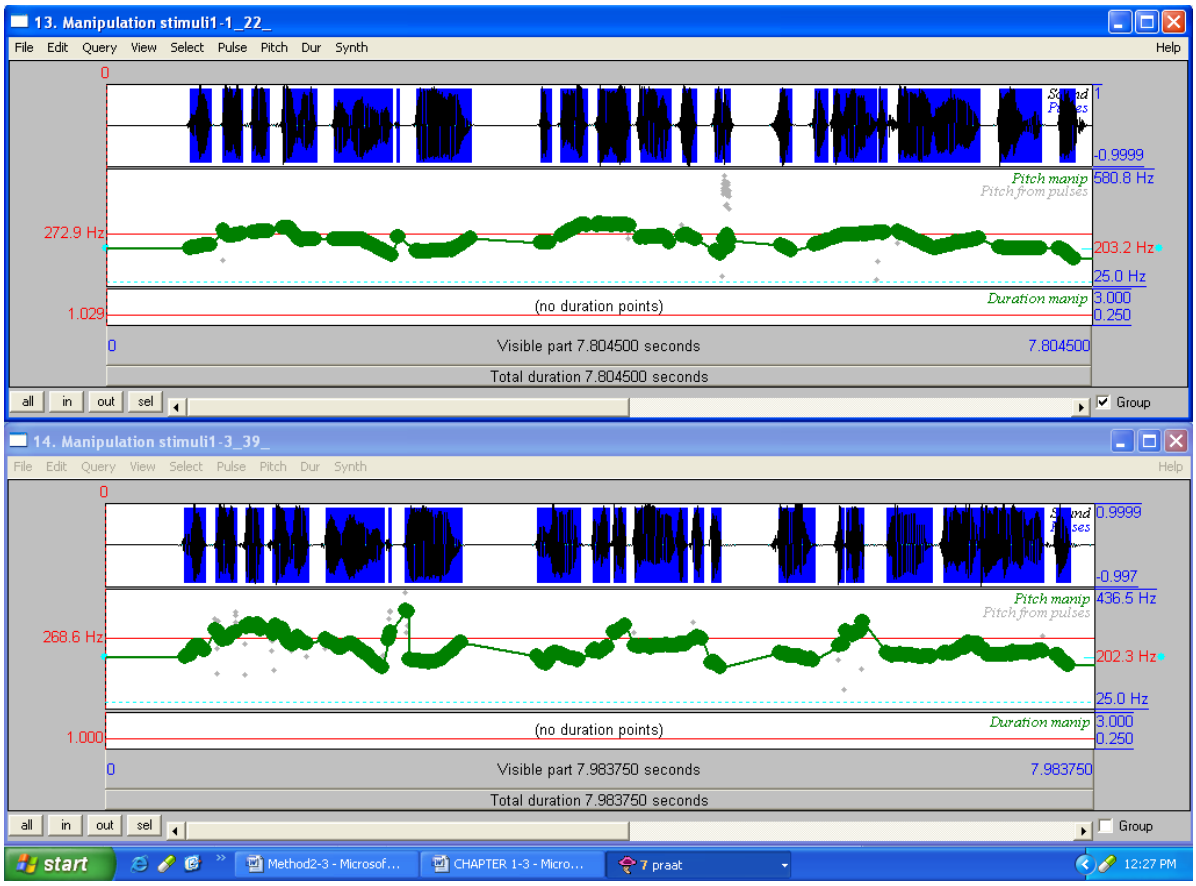


Figure 2-1. A typical choral signal (top) vs. a temporally altered signal (bottom) of the stimulus: The policeman and detective had ticketed the Canadian by mistake. The sentence is preceded by the unaltered carrier phrase: The sentence you have to read is.(Screen shots are taken from Praat.)

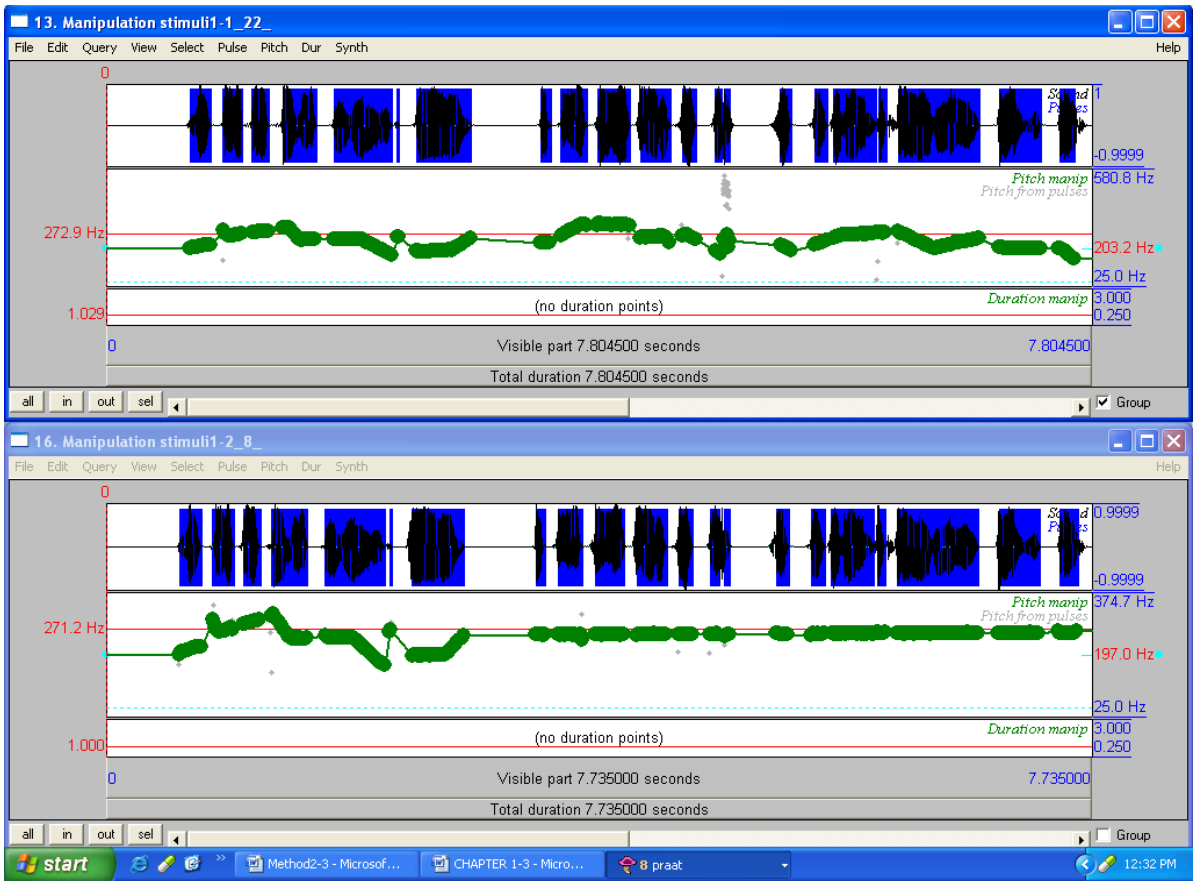


Figure 2-2. A typical choral signal (top) vs. a pitch altered signal (bottom) of the stimulus: The policeman and detective had ticketed the Canadian by mistake. The sentence is preceded by the unaltered carrier phrase: The sentence you have to read is.(Screen shots are taken from Praat.)

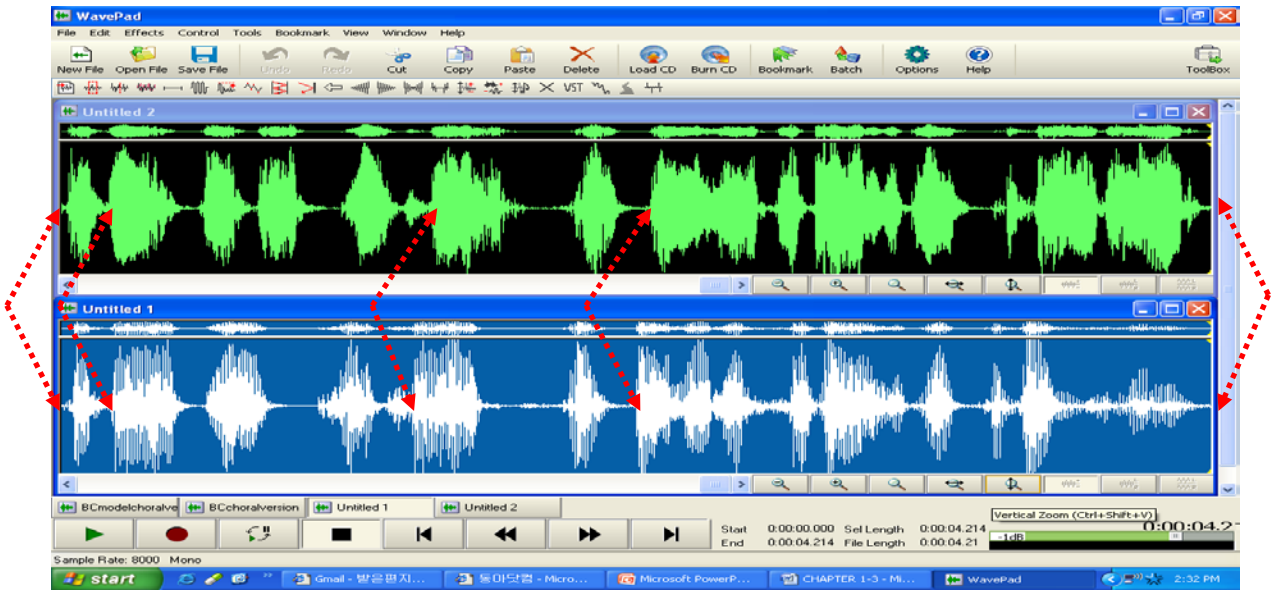


Figure 2-3. Entrainment assessment of the five reference points (i.e., The, director, patriot, donated, Benjamin) in the participant's response (bottom) to analogous points within the choral model speech (top) for the sentence The director of Patriot has donated the valuables to Benjamin. (Screen shots are taken from Praat).

CHAPTER 3
RESULTS

Speaking Group and Task Effects on Fluency

As noted in Chapter 2, stuttering frequency (i.e., percentage of syllables that featured stuttered speech) was one of the main dependent variables in the present study. The main questions to be investigated were whether there was a significant difference in stuttering frequency among the various experimental conditions, and whether there was a significant difference between groups in the way they reacted to altered auditory feedback. As mentioned in the previous section, judgments of stuttering behavior were based upon analysis of both verbal and nonverbal behaviors. For the participants who stuttered, verbal behaviors that were judged to be symptomatic of stuttered speech mainly consisted of repetition of sounds, syllables, or isolated words, audible or inaudible prolongations of speech sounds, and articulatory postures that appeared to feature excessive physical tension (i.e., “blocks”). Nonverbal behaviors that were judged to be symptomatic of stuttered speech for the participants who stuttered included extraneous rhythmic movements of non-speech musculature, excessively tense non-speech movements, gaze aversion produced in conjunction with repeated or prolonged speech, and rapid, repeated eye blinking in conjunction with word initiation. For the participants who did not stutter, the analysis focused on determining the frequency of stutter-like disfluency, that is, sound, syllable, and word repetitions and prolongations in speech. This was because people who do not stutter rarely produce the nonverbal behaviors that are observed in stuttered speech, and that was the case in this study, as well. Descriptive statistics for the stuttering frequencies within the two speaker groups in each of the experimental conditions are summarized in Table 3-1.

As expected, participants who do not stutter spoke very fluently in both of the normal auditory feedback conditions (i.e., typical solo feedback condition (NAF), typical choral

feedback condition (CH-NAF)) (see Table 3-1). Inspection of Table 3-1 also reveals that participants who do not stutter also exhibited very little stutter-like disfluency in any of the altered auditory feedback conditions, which suggests that the AAF conditions were not especially difficult for them to complete. Analysis of raw summary data in Table 3-1 revealed that every participant who did not stutter exhibited no stutter-like behavior (i.e., stuttering frequency = 0) in at least one of the speaking conditions.

Table 3-1 also shows disfluency results for participants who stutter. As can be seen, participants who stutter produced, on average, at least five times as much stuttering in the typical solo reading condition as they did in the various altered auditory feedback conditions (i.e., 3.71/0.65). Even in the solo reading with non-altered auditory feedback (i.e., NAF) condition, however, most of the participants who stutter did not have a particularly high frequency of stuttering. The exception was participant number S06, who produced stuttered speech on 14.52% of the syllables during solo NAF condition. This participant reported having difficulty in fluently producing words that begin with [h] and [f]. Consistent with this, the participant was observed to stutter on almost every word that began with these sounds (e.g., hibernation, happening, federal). Like the non-stuttering participants, the speakers who stutter exhibited relatively little stuttering during the various altered auditory feedback conditions. Thus, on the surface, it appeared as if those modifications in auditory feedback played a positive role in inducing fluency of participants who stutter.

Statistical Approach for Analyzing the Stuttering Frequency Data

Because of the relatively small number of participants in the two subject groups in the study and resulting concerns about meeting the assumptions of normally distributed data (Conover, 1980) and homogeneity of variance that are needed for parametric statistical tests, nonparametric statistical methods were used to complete the main analyses associated with

stuttering frequency. Three different nonparametric statistics were used. Within-subject analysis of stuttering frequency across the different speaking conditions was performed using the Friedman test, a nonparametric statistic based on rank-based procedures. To do the planned within-subject, post-hoc comparisons, the paired-sample, Wilcoxon signed rank test was used. Finally, the Mann-Whitney U test was used to complete planned, between-subject comparisons. To control for Type I error across the planned comparisons, the overall alpha level ($\alpha = .05$) was divided by the number of comparisons within each family of tests (Marasculio & McSweeny, 1977).

Stuttering Frequency

Between-Subject Comparisons

Although it was shown that the stuttering participants stuttered less than was expected, their mean frequency of stutter-like behaviors during NAF (M =3.71; SD = 4.65) was nonetheless significantly higher (Z = -3.508; $p < .001$) than that of the participants who did not stutter (M = 0.01; SD = 0.03). A significant difference (Z = -2.139; p = .05) was also found in the frequency of stuttering behaviors produced by participants who do stutter and participants who do not stutter during typical choral reading (CH-NAF). Once again, participants who stutter had a significantly greater percentage of syllables stuttered (M = 0.28; SD = 0.36) than participants who do not stutter (M = 0.03; SD = 0.06). As expected, however, participants who stutter still spoke relatively fluently during CH-NAF. Improvements in speech fluency were also accompanied by a relative absence of nonverbal stuttering-related behaviors, such as excessive physical tension and eye blinking.

Between-subject comparisons for the frequency of stuttering behaviors for all solo-altered conditions and all choral-altered conditions were also performed. To do so, the average stuttering frequency for each of the altered conditions was computed (i.e., average for solo-altered

conditions = (delayed auditory feedback (DAF) + frequency-altered feedback (FAF)/2); average for choral-altered conditions = (temporally-altered choral feedback (CH-TAF) + pitch contour-altered choral feedback (CH-PAF)/2)). No significant between-subject differences were found in the frequency of stuttering behaviors during either solo altered auditory feedback (Z = -1.565; p = .13) or choral altered auditory feedback (Z = -1.540; p = .13). The results indicated that participants who stutter, as a group, spoke as fluently as participants who do not stutter during both solo-altered auditory feedback and choral-altered feedback.

Within-Subject Comparison for Participants Who Stutter

Results from a Friedman test showed a significant within-subject effect for Speaking Condition (χ^2 = 20.3; df =6; p = .003). The result indicated that there was a significant difference in stuttering frequency across the seven experimental speaking conditions for the speakers who stutter. Planned post hoc tests were performed using the paired-sample Wilcoxon signed rank test. The first comparison examined whether participants who stutter spoke with different levels of fluency during typical choral reading (CH-NAF) and typical solo reading (NAF). As expected, the test showed a significant difference in the frequency of stuttering behaviors between the two speaking conditions (Z = -2.521; p = .012), with the stuttering behaviors of participants who stutter being less frequent during typical choral reading than during normal auditory feedback.

The next comparison examined whether alterations in the accuracy of prosodic information affected the extent to which choral auditory feedback enhances fluency. To do this, the frequency of stuttering behavior for typical choral reading and the average frequency of stuttering behaviors of altered choral readings (i.e., CH-TAF, CH-PAF) were compared. The Wilcoxon signed rank test showed no significant difference in the frequency between the typical and the altered choral reading conditions (Z = -0.508; p = .611). Thus, it appeared that alterations in the accuracy of prosodic information did not affect the extent to which choral auditory feedback

enhanced the speech fluency of speakers who stutter. A third comparison examined whether alterations in duration-based prosodic feedback affected speech fluency differently than alterations in pitch-based prosodic feedback. For this, the temporally-altered choral reading (CH-TAF) and the pitch contour-altered choral reading condition (CH-PAF) were compared in terms of stuttering frequency. The Wilcoxon test showed no significant difference between the two altered choral reading conditions (Z = 0.00; p = 1.00). Thus, it appeared that alterations in duration-based prosodic feedback did not affect speech fluency differently than alterations in pitch-based prosodic feedback.

The frequency in stuttering behaviors between typical choral reading and multi-speaker babble choral reading conditions (CH-BAF) were also compared. As discussed earlier, the multi-speaker babble noise was presented as a contrast to the altered feedback conditions, in that it contains essentially prosodic noise (i.e., overlapping word durational patterns and pitch contours). The Wilcoxon test showed no significant difference in stuttering frequency (Z = -0.647; p= .518) between the typical choral reading and the multi-speaker babble choral feedback (CH-BAF). Thus, it appeared that manipulation in accuracy of segmental and prosodic information did not markedly affect the extent to which the choral auditory feedback facilitated participants' speech fluency.

Lastly, the frequency of stuttering behaviors between typical solo reading (NAF) and the various altered conditions were compared. The frequencies in stuttering behaviors between typical solo reading and solo altered reading condition (i.e., DAF, FAF) were compared. In this case, the adjusted p-value was .025 (i.e., = .05/2). The Wilcoxon test showed a significant difference in stuttering frequency between NAF and DAF (Z = -2.524, p = .012). A significant difference in stuttering frequency was also found between NAF and FAF (Z = -2.521; p = .012).

Typical solo reading and altered choral reading conditions (i.e., CH-TAF, CH-PAF, CH-BAF) were also compared in terms of stuttering frequency. In this case, the adjusted *p*-value was .017 (= .05/3). The test showed a significant difference between NAF and CH-PAF (Z = -2.380; p = .017). A significant difference in stuttering frequency was also found between NAF and. CH-TAF (Z = -2.521; p = .012). As well, a significant difference in stuttering frequency was also found between NAF and CH-BAF (Z = -2.521; p = .012). These results suggested that participants who stutter spoke as fluently while receiving altered auditory feedback, regardless of the source for that feedback (i.e., own voice feedback or another speaker's voice feedback).

Within-Subject Comparisons for Participants Who Do Not Stutter

With the participants who do not stutter, the Friedman test showed no significant within-subject effect for Speaking Conditions (χ^2 = 9.038; df =6; p = .171). Participants who did not stutter appeared to speak with comparable levels of fluency in each of the experimental speaking conditions.

Conversational Speech Sample and Intervening Passage Readings

Prior to the main experiment, as mentioned in Chapter 2, conversational speech samples were collected from each participant. The Wilcoxon signed rank test was used to test if the conversational speech samples of participants who stutter differed significantly in stuttering frequency when compared with their responses collected from the NAF condition. Summary statistics for both conditions are provided in Table 3-2. The test showed no significant difference in stuttering frequency between the two speaking conditions (Z = -0.169; p = .866). There was, however, a moderate positive correlation between stuttering frequency during the conversational speech sample and stuttering frequency during the participants' responses during NAF (*rho* = .571). It has been reported that people who stutter tend to speak less fluently in conversational situations than they do during oral reading (Bloodstein, 1995). In the present study, however,

some participants who stutter were observed to stutter more during oral reading than they did in the conversational context.

Stuttering frequencies during the “distraction tasks” (i.e., reading passages that were performed between experimental conditions) were also analyzed for the participants who stutter. As shown in Figure 3-1, it appears that, aside from participant S06, participants who stutter showed no notable change in stuttering frequency across the passage readings.

Speaking Group and Task Effects on Speaking Rate

Speaking rate (i.e., mean number of syllables uttered per second) was also examined to see if there was a significant difference in performance between participants who stutter and participants who do not stutter across the speaking conditions. As suggested in Figure 3-2, the participants who stutter, as a group, seemed to speak slower than the participants who do not stutter across the experimental speaking conditions. This difference seemed especially apparent during the normal solo auditory feedback (NAF), as compared to the other experimental speaking conditions. Both participants who stutter and participants who do not stutter also appeared to speak more slowly during delayed auditory feedback (DAF) than they did during any other solo or choral altered feedback conditions. A series of nonparametric tests were conducted to assess the main research questions pertaining to speaking rate.

Between-Subject Comparisons

Between-group comparisons for each of the seven experimental speaking conditions were conducted. The Mann-Whitney U test showed a significant group difference (Z = -3.366; p < .001) in speaking rate only during typical solo reading (NAF), indicating that participants who stutter spoke significantly slower than participants who do not stutter during NAF but not during the other experimental speaking conditions (Z = -1.052, p =.293 for DAF; Z = .-1.788, p = .074

for FAF; Z = -2.526, p = .012 for CH-NAF; Z = -2.209, p = .027 for CH-PAF; Z = -2.524, p = .012 for CH-TAF).

Within-Subject Comparisons for Participants Who Stutter

Results of a Friedman test showed no significant within-subjects effect (χ^2 = 8.373; df = 6; p = .212) for Speaking Conditions, suggesting that participants who stutter spoke at a relatively steady rate across the experimental speaking conditions. As discussed above, however, participants who stutter spoke slower during NAF than they did in the other speaking conditions since they are more likely to have stuttering behaviors in the speaking condition. The nonparametric test, however, showed no significant within-subjects difference.

Within-Subject Comparisons for Participants Who Do Not Stutter

With the participants who do not stutter, the Friedman test showed a significant within-subject effect for Speaking Condition (χ^2 = 35.304; df =6; p < .001). Again, the Wilcoxon signed rank test was used to conduct planned post hoc comparisons. The first comparison assessed whether there was a significant difference in the speaking rate between solo typical (NAF) and the solo altered reading conditions (i.e., DAF, FAF). In this case, the p-value for each "family of tests" was .017 (i.e., = .05/3). The Wilcoxon test showed significant differences in speaking rate between NAF and FAF (Z = -2.521; p = .012), between NAF and DAF (Z = -2.524; p = .012), and between DAF and FAF (Z = -2.380; p = .017). These results indicated that participants who do not stutter spoke at different rates across the three solo reading conditions. As noted in Figure 3-2, more specifically, participants spoke slowest during DAF and fastest during NAF, with FAF in the middle.

The second comparison assessed whether there was a significant difference in the speaking rate between typical choral (CH-NAF) and altered choral reading conditions (i.e., CH-TAF, CH-PAF). A series of three Wilcoxon tests showed no significant difference between CH-NAF and

CH-TAF (Z = -1.612; p = .107), between CH-NAF and CH-PAF (Z = -0.560; p = .575), or between CH-TAF and CH-PAF (Z = -0.771; p = .441). The results indicated that participants who do not stutter spoke at a relatively steady rate across the three choral reading conditions.

Entrainment Analysis

The Reference Point Entrainment Analysis

As discussed in the previous chapter, the reference-point entrainment analysis was done by comparing the onset times of five distinct phones located at five different locations (i.e., one sentence-initial phone, 3 sentence-medial phones, one sentence-final phone) within the participants' fluent responses during the choral reading conditions against the same phones as they were produced in the reference (i.e., choral) speech signal. To do so, information about specific time for each of the reference phones within participants' fluent responses and within the choral models were respectively measured and their differences in time were then calculated. Ultimately, differences in phone onset time between the participants and the choral speech reference were analyzed to identify differences between and within subjects. It was hypothesized that participants who stutter would show more entrainment to the choral signals than participants who do not stutter and that entrainment would be greatest for participants who showed the most fluency benefit from the choral speech conditions.

Results from the reference point entrainment analysis are summarized in Figure 3-3. As shown in the figure, participants who stutter appeared to show more temporal entrainment to the choral model than participants who do not stutter did across the three choral feedback conditions. Specifically, they appeared to show the most temporal entrainment to the reference phones during typical choral feedback condition (CH-NAF). As shown in Figure 3-3-(a) (entrainment for typical choral reading), participants' responses tended to follow the choral model closely through the course of the sentences during the speaking condition.

Statistical Approach for Analyzing the Entrainment Data

Again, because of the relatively small number of participants in the two subject groups in the study and resulting concerns about meeting the assumptions of normally distributed data (Conover, 1980) and homogeneity of variance that are needed for parametric statistical tests, nonparametric statistical methods were used to analyze the entrainment data. The Friedman test was conducted to assess if there were significant within-subject differences in the reference entrainment across the 5 reference points. To do the planned post hoc paired samples comparisons, furthermore, the Wilcoxon signed rank test was used. The Mann-Whitney U test was also conducted to complete planned, between-subject comparisons. Again, to control for Type I error across the planned comparisons, the adjusted alpha value was used by dividing the overall alpha value (i.e., .05) by the number of comparisons within each family of tests (Marasculio & McSweeny, 1977).

Between-Subject Comparisons

Results from the Mann-Whitney U test revealed no significant group differences in each of the 5 reference entrainment points during pitch contour-altered choral reading (CH-PAF) (Z = -1.789, p = .083 for sentence-initial phone (W1); Z = -.211, p = .878 for first sentence-medial phone (R2); Z = -1.261, p = .234 for second sentence-medial phone (W3); Z = -1.158, p = .279 for third sentence-medial phone (W4); Z = -1.581, p = .130 for sentence-final phone (W5)) and temporally-altered choral reading condition (CH-TAF) (Z = -.105, p = .959 for W1; Z = -.527, p = .645 for W2; Z = -1.684, p = .105 for W3; Z = -1.998, p = .051 for W4; Z = -1.792, p = .083 for W5). The results indicated that during those altered choral reading conditions, there were no significant differences in each of the reference points between groups in the extent to which participants' responses were temporally mapped on to the choral models. However, group differences were found for some later reference points during typical choral reading (CH-NAF)

(Z = -2.419, p = .015 for W3; Z = -2.316, p = .021 for W4; Z = -2.210, p = .028 for W5). The results suggest that participants who stutter and participants who do not stutter showed different temporal entrainment in each of the later reference points during CH-NAF. As indicated in Figure 3-3(a), participants who stutter showed more entrainment to the reference points than participants who do not stutter did during the typical choral reading condition.

Within-Subject Comparisons for Participants Who Stutter

With participants who stutter, the Friedman test showed no significant difference in the entrainment across the 5 reference points during CH-NAF (χ^2 = 8.579; p = .073). However, significant differences were found across the reference entrainment points during CH-PAF (χ^2 = 18.217; p = .001) and CH-TAF (χ^2 = 15.567; p = .004). To do post hoc paired sample comparisons, the Wilcoxon test was used and showed significant differences in the reference entrainment between W1 and W2 during CH-TAF (Z = -2.524; p = .012). A significant difference was also found between W3 and W4 (Z = -2.527; p = .012) during CH-PAF. The adjusted p-value here was .013 (i.e., .05/4). These results suggest that overall temporal structure for sentence responses for participants who stutter was similar to that used by the choral speech model, in particular, during CH-NAF.

Within-Subject Comparisons for Participants Who Do Not Stutter

The Friedman test showed significant differences in the entrainment across the 5 reference points during CH-NAF (χ^2 = 31.3; p < .001), during CH-PAF (χ^2 = 31.3; p < .001), and during CH-TAF (χ^2 = 29.3; p < .001). Furthermore, the Wilcoxon test showed significant differences in the reference entrainment between W1 and W2 (Z = -2.524; p = .012), between W2 and W3 (Z = -2.521; p = .012), and between W3 and W4 (Z = -2.536; p = .011) during CH-NAF. Significant differences were also found in the reference entrainment between W2 and W3 (Z = -2.524; p = .012), between W3 and W4 (Z = -2.524; p = .012), and between W4 and W5 (Z = -

2.521; p = .012) during CH-PAF. For CH-TAF, lastly, significant differences were also found in the reference entrainment between W1 and W2 (Z = -2.536; p = .011), between W2 and W3 (Z = -2.524; p = .012), and between W3 and W4 (Z = -2.521; p = .012). These results indicated that overall temporal structure for sentence responses for participants who do not stutter was not similar to that used by the choral speech model. This seemed true across the three choral reading conditions.

Relationship between Fluency Patterns and the Reference Point Entrainment

To obtain insight into whether those who benefited most from choral speech models were those who entrained most closely to choral speech models, a correlation analysis was conducted. Participants' percentage of fluency improvement scores was correlated with participants' average entrainment across the reference points. The correlation analysis was conducted for the typical choral reading condition (CH-NAF). To do the correlation analysis, first of all, reduction rate in stuttering behaviors of participants who stutter from typical solo reading (NAF) to typical choral reading condition (CH-NAF) was computed by the following formula: ((percentage of stuttering behaviors during NAF – percentage of stuttering behaviors during CH-NAF)/percentage of stuttering behaviors during NAF) * 100)). Then, the average entrainment value across the 5 reference points was calculated. The Spearman test for nonparametric correlation showed a modest positive correlation (*rho* = .355) between the extent of reduction stuttering frequency and the amount of entrainment with choral speech models. Thus, it appeared the average entrainment across the reference points during typical choral reading account for only some of the variance in participants' percentage improvement in fluency..

Overall Speech Rate Entrainment Analysis

The overall speech rate analysis was done to determine the extent to which the speech rates of the participants throughout an entire sentence matched those of the choral speech model while

the sentences were being read aloud. To do so, first of all, information about speech rate (i.e., number of syllables uttered per second) for each of participants' fluent responses and the choral models were respectively measured and their differences in time were then calculated. As in the reference entrainment analysis, nonparametric statistics were used to determine if the average difference in speech rates between participants' responses and the choral models was significantly different between and within groups. Results from the speech rate entrainment analysis are summarized in Figure 3-4.

Between-Subject Comparisons

The Mann-Whitney U test showed significant group differences in the speech rate entrainment during all of the three choral reading conditions (Z = -2.524; p = .012 for CH-NAF; Z = -2.104; p = .035 for CH-PAF; Z = -2.629; p = .007 for CH-TAF). The results indicated that participants who stutter and participants who do not stutter spoke at different speaking rates from those of the choral models in each of the choral experimental conditions. It turned out participants who do not stutter spoke at a significantly faster rate to that of the choral model across the choral experimental conditions.

Within-Subject Comparisons for Participants Who Stutter

The Friedman test showed no significant differences in the speech rate entrainment across the three choral experimental conditions (χ^2 = 3.325; p = .197). The result suggests that participants who stutter spoke at a similar speaking rate as that of the choral models across the choral experimental conditions.

Within-Subject Comparisons for Participants Who Do Not Stutter

With participants who do not stutter, however, significant differences in the speech rate entrainment were found across the experimental choral reading conditions (χ^2 = 8.968; p = .011). The Wilcoxon test further showed significant differences in the speech rate entrainment between

CH-NAF and CH-TAF (Z = - 2.383; p = .017) and between CH-PAF and CH-TAF (Z = -2.521; p = .012). However, no significant difference was found in the speech rate entrainment between CH-NAF and CH-PAF (Z = -.980; p = .327). In this case, the adjusted p-value was .017 (i.e., .05/3). The results indicated that the speech rate entrainment values (i.e., differences in speech rates between participants' responses and the choral models) were largest particularly during CH-TAF. As shown in Figure 3-4, participants who stutter spoke at the fastest speaking rate during the temporally-altered choral reading condition.

Reading Accuracy

Reading accuracy (i.e., error frequency in reading) and types of errors in reading were also investigated. Summary data for reading errors made by participants who stutter and participants who do not stutter across the experimental speaking conditions are summarized in Figure 3-5. By simple inspection of reading error frequency results, it appeared as if participants who stutter made more errors in reading than participants who do not stutter. Differences in reading error frequency between participants who stutter and participants who do not stutter also appeared to be relatively larger during the typical reading conditions (NAF, CH-NAF) and participants who stutter appeared to make less reading errors during the other altered reading conditions. Types of reading errors most frequently observed included omissions (e.g., summer semester → semester, the college→ college) and substitutions (e.g., Saturday→Sunday, talking→ taking, negative results→ negative effects) .

Between-Subject Comparisons

The Mann Whitney U test showed no significant differences in the mean frequency of reading errors made by participants who stutter and participants who do not stutter (Z = -1.867, p = .062 for NAF; Z = -0.058, p = .953 for DAF; Z = -1.108, p = .268 for FAF; Z = -1.449, p = .147 for CH-NAF; Z = -0.648, p = .517 for CH-PAF; Z = -0.772, p = .440 for CH-TAF).

Within-Subject Comparisons for Participants Who Stutter

The Friedman test showed no significant difference in the mean frequency of reading errors made by participants who stutter across the seven experimental reading conditions (χ^2 = 11.853; *df* =6; *p* = .065). The result suggested that participants who stutter did not make reading errors at a different rate across the experimental reading conditions.

Within-Subject Comparisons for Participants Who Do Not Stutter

The Friedman test showed no significant difference in the mean frequency of reading errors made by participants who do not stutter across the seven experimental reading conditions (χ^2 = 3.459; *df* =6; *p* = .749). Again, the result indicated that participants who do not stutter did not make reading errors at a different rate across the experimental reading conditions.

Table 3-1. Frequency of stutter-like behavior for participants across conditions

Subject number	Speaking Conditions						
	Solo			Choral			
	NAF	DAF	FAF	CH-NAF	CH-TAF	CH-PAF	CH-BAF
S1	4.93	1.07	1.43	0.27	0.72	0.36	3.59
S2	0.18	0.09	0.09	0	0.09	0.18	0
S3	3.32	0.18	0.18	0.81	0.90	1.07	0.90
S4	1.70	0	0.08	0.09	0.09	0	0.98
S5	3.38	0.63	0.99	0.90	1.34	0.18	0.81
S6	14.53	1.61	0	0.09	0.18	1.43	0
S7	0.84	0	0	0	0	0.26	0
S8	0.81	0	0.09	0.09	0.09	0	0
M	3.71	0.45	0.35	0.28	0.35	0.40	0.65
SD	4.65	0.61	0.55	0.36	0.44	0.55	0.88
NS1	0	0	0	0	0	0	0
NS2	0	0.08	0	0	0	0	0
NS3	0	0	0	0	0.09	0	0
NS4	0	0	0.15	0	0.09	0.08	0
NS5	0.17	0.08	0.60	0.08	0	0.34	0.08
NS6	0	0	0	0	0	0	0
NS7	0	0	0.17	0	0.08	0.08	0
NS8	0.08	0	0	0	0.27	0.08	0
M	0.01	0.02	0.12	0.03	0.07	0.07	0.03
SD	0.03	0.04	0.21	0.06	0.11	0.12	0.06

NAF = Normal auditory feedback; DAF = delayed auditory feedback; FAF = frequency altered feedback; CH-NAF = typical choral feedback; CH-TAF = temporally-altered choral feedback; CH-PAF = pitch contour-altered choral feedback; CH-BAF = choral feedback with multi-speaker babble noise. S = participants who stutter; NS = participants who do not stutter. *M* =mean; *SD* =standard deviation

Table 3-2. Percentage of stuttering behaviors for participants who stutter during conversational speech versus typical solo reading condition (NAF)

Subject number	Conversational speech	Typical solo reading (NAF)
1	2.2	4.93
2	0.67	0.18
3	0.33	3.32
4	3.3	1.70
5	4.5	3.38
6	4.0	14.53
7	2.25	0.84
8	0.09	0.81
M	2.17	3.71
SD	1.83	4.65

M =mean; *SD* =standard deviation

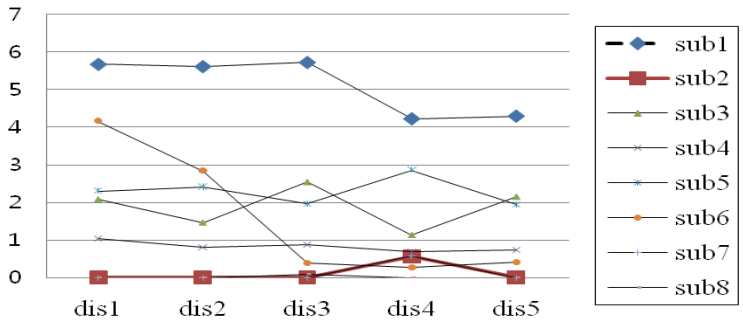


Figure 3-1. Stuttering frequency (percent of syllables stuttered) for participants who stutter across the distraction reading passages (dis1, dis2, dis3, dis4, dis5 = the five randomly ordered passage readings); Y-axis: percent of syllables stuttered

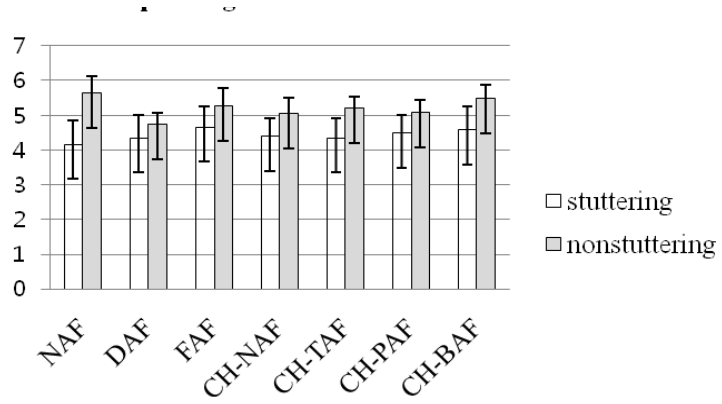


Figure 3-2. Speaking rate (number of syllables uttered per second) for participants who stutter and participants who do not stutter across the experimental speaking conditions (NAF = Normal auditory feedback; DAF = delayed auditory feedback; FAF = frequency altered feedback; CH-NAF = typical choral feedback; CH-TAF = temporally-altered choral feedback; CH-PAF = pitch contour-altered choral feedback; CH-BAF = choral feedback with multi-speaker babble noise); Y-axis: syllables per second

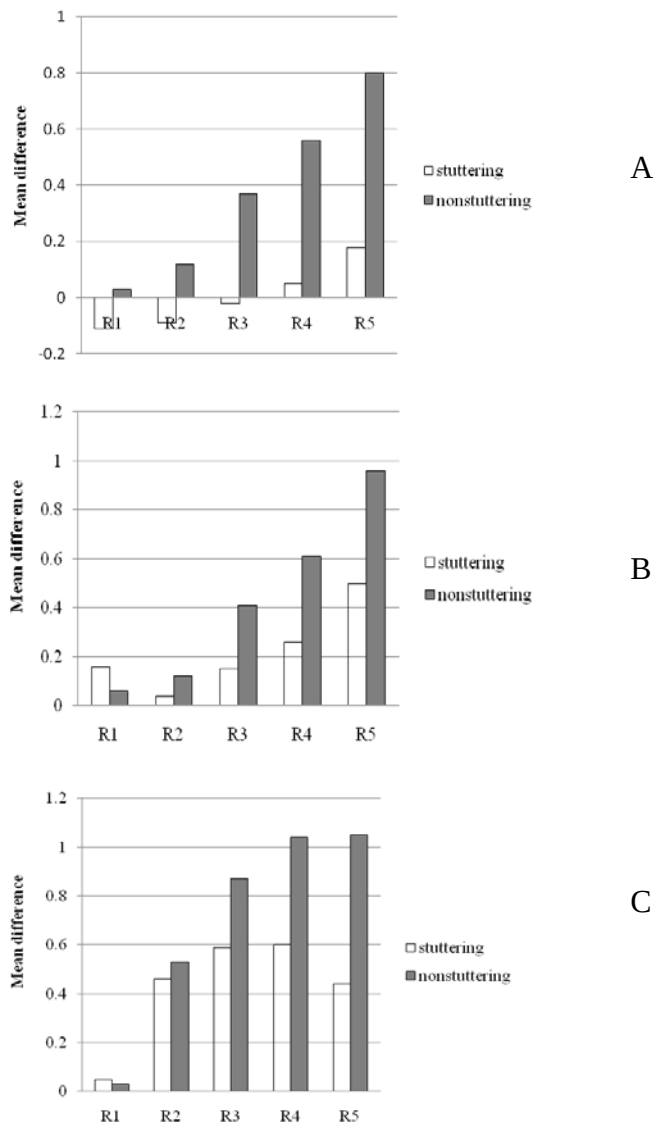


Figure 3-3. Reference point entrainment data for the three choral reading conditions (R1 = sentence-initial reference phone; R2 = first sentence-medial reference phone; R3 = second sentence-medial reference phone; R4 = third sentence-medial reference phone; R5 = sentence-final reference phone; Mean difference = mean difference in phone onset time between the participants and the choral speech reference) (A) Entrainment for Typical Choral Reading (B) Entrainment for Choral Reading with Pitch Contour-altered Feedback (C) Entrainment for Choral Reading with Temporally-altered Feedback

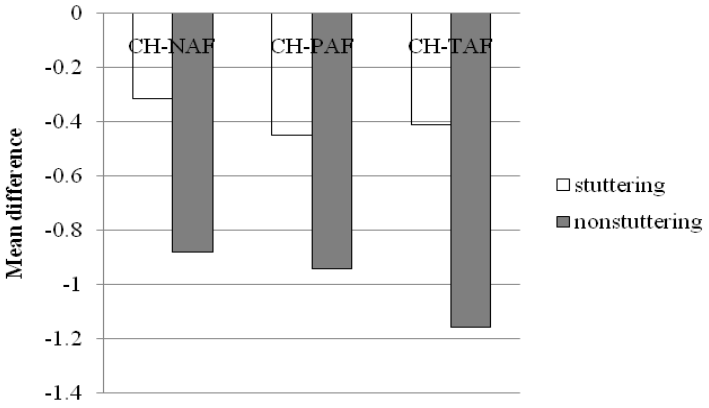


Figure 3-4. Mean differences in speaking rates (syllables per sec) between participants and choral speech models for the three experimental choral speaking conditions (Mean difference: mean difference in speech rate between participants' responses and the choral models; CH-NAF = typical choral feedback; CH-TAF = temporally-altered choral feedback; CH-PAF = pitch contour-altered choral feedback)

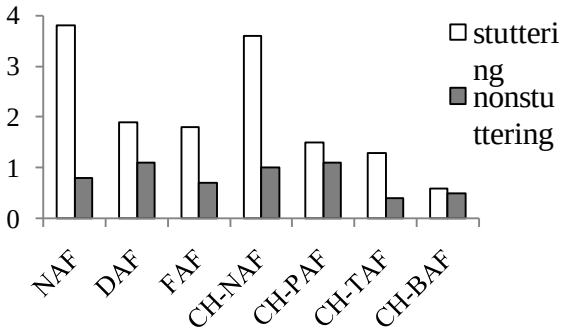


Figure 3-5. Mean of reading error of participants who stutter and participants who do not stutter across the experimental speaking conditions (NAF = Normal auditory feedback; DAF = delayed auditory feedback; FAF = frequency altered feedback; CH-NAF = typical choral feedback; CH-TAF = temporally-altered choral feedback; CH-PAF = pitch contour-altered choral feedback; CH-BAF = choral feedback with multi-speaker babble noise) Y-axis: Percent of reading error (=(sum of errored words /60)*100) Note: 60 is the total number of sentences in each condition

CHAPTER 4
DISCUSSION

Prosodic Alteration of Choral Feedback and Fluency Enhancing Effects

As expected, participants who stutter spoke less fluently while receiving non-altered normal auditory feedback of their own voice (i.e., NAF), but their fluency was significantly improved in response to non-altered auditory feedback of another speaker's voice (i.e., CH-NAF). The fluency enhancing effects during typical choral speech replicates findings reported in previous studies (Andrews et al., 1982; Ingham & Packman, 1979; Rami, 2000). Furthermore, the fluency enhancing effects of choral speech were observed even when prosodic information within the choral model speech (i.e., pitch contour, temporal pattern) was dramatically altered. As shown in the present study, participants who stutter spoke more fluently during temporal pattern altered choral feedback (i.e., CH-TAF) and during pitch contour altered choral feedback (i.e., CH-PAF) than they did when speaking alone with normal auditory feedback. Thus, findings from the present study do not support the idea that alterations in the accuracy of prosodic information affect the extent to which typical choral auditory feedback enhances fluency.

As discussed earlier, stuttering has been hypothesized as a timing-related deficit (Kent, 1984; Van Riper, 1982; Alm, 2004). Mechanisms associated with choral speech have been used to support this hypothesis. For example, Kent (1984) proposed that careful monitoring of another person's speech makes it possible for speakers who stutter to generate the temporal patterns that are necessary for fluent speech. He argued that the mechanisms underlying choral speech were similar to those observed in "the metronome effect" (i.e., fluency inducement in response to an external rhythmic signal). According to Kent, speakers who stutter use the other speaker's voice as an external signal which provides an external timing (or rhythmic) pattern that the speaker then utilizes to extract temporal information about ongoing speech.

Results from the entrainment analysis in the present study seem partially supportive for this explanation. As discussed in Chapter 3, participants who stutter showed more entrainment to the reference phones, especially during typical choral feedback condition (CH-NAF) than the participants who do not stutter. Accordingly, it appeared that participants who stutter relied upon the typical choral signal more than non-stuttering participants did. Participants who stutter also appeared to benefit from the choral signal more than the participants who do not stutter, as evidenced by the improvements in their speech fluency. However, based on the results of this study, monitoring or extracting precise temporal patterns from the choral speech did not seem to be the main factor behind fluency inducement for the participants who stutter during choral speech.

As shown in the method chapter, the temporally-altered versions of choral feedback were created to be mismatched with the original choral versions in terms of word durational pattern. Thus, it was anticipated that the temporally-altered choral feedback would make it hard for participants who stutter to extract normal temporal patterns that are necessary for fluent speech. As shown in the study, however, participants who stutter spoke fluently even when they received the temporally-altered choral feedback. At this point, however, it needs to be noted that fluency enhancing effect observed during temporally-altered choral reading condition (CH-TAF) does not necessarily mean that participants who stutter used the prosodic information in the choral signal in its entirety. For example, it may be that speakers relied upon selective temporal cues in the choral signal to attain the fluency enhancing effects observed during choral speech. One form of temporal information that speakers might utilize is vowel duration. Even though the word duration during the CH-TAF condition was mismatched to specific lexical items, the range of vowel durations that were presented to speakers were still typical of those observed during

speech. As discussed in Chapter 1, some researchers (Packman, Code, & Onslow, 2007; Packman, Onslow, & Menzies, 2000; Packman, Onslow, Richard, & Doorn, 1996) have argued that changes in syllabic stress, mainly manifested in the vowel duration across syllables, can be the critical feature of fluency enhancing conditions (e.g., rhythmic speech, prolonged speech, syllable-timed speech).

Writing from a somewhat different perspective, Alm attempted to explain the fluency enhancing effects of choral speech in neurophysiological terms. Basically, Alm viewed stuttering as a timing-related deficit, stemming from the involvement of the basal ganglia circuit. Alm noted that the basal ganglia circuit plays a critical role producing timing cues during normal (or "automatized") speech production. Explaining the rhythmic effect (i.e., fluency enhancement in response to external rhythmic signal), Alm (2004) argued that rhythmic stimuli provide external cues for the timing of each syllable.

According to Alm, speakers with a dysfunctional basal ganglia circuit (i.e., people who stutter) have a problem with generating internal timing cues and accordingly, they have difficulty producing sequential speech movements. However, when speakers who stutter talk under novel or "un-automatized" conditions, such as DAF, FAF, and choral speech, Alm claimed that speakers utilize another mechanism for speech timing control: the cerebellar-premotor system. That is, Alm argued that participants who stutter cannot generate internal timing cues for speech movement because of the dysfunctional basal ganglia system. However, they can generate timing cues from through the activation of cerebellar-premotor system, which plays a role in extracting timing information from sensory stimuli and which is likely to be active during choral speech (Penhune et al., 1998).

In this view, it can be still possible for speakers who stutter to extract temporal information related to syllabic vowel duration even when the overall prosodic patterning within an utterance is distorted or altered. As mentioned in Chapter 2, with respect to altering temporal pattern, the concept of relative prominence was used in the present study. When several words are combined to form compound nouns or phrases, stress pattern is determined on the basis of relative prominence among words (Spencer, 1995). Thus, in the present study, word durational pattern was considered and manipulated. However, it can be also argued that manipulating syllabic vowel duration or its variability across syllables can be another possible way to examine if participants who stutter monitor or extract temporal information from the choral signal by which stuttering can be significantly reduced. Given the results of the present study, to sum up, there is one sure thing that can be mentioned. That is, participants who stutter attain fluency through processes other than precise, word-by-word monitoring or extracting temporal information associated with word durational pattern from the external choral speech.

As shown in the present study, furthermore, fluency enhancing effects were also observed when participants who stutter read aloud the sentences while receiving multi-speaker babble choral feedback. As mentioned in Chapter 2, the main rationale for using the multi-speaker babble noise was that the babble noise is, in a sense, another form of altered choral feedback in that the signal lacks predictable prosodic (and segmental) information. Even though a listener can recognize conversational babble as human speech, it is not easy for speakers who stutter to readily extract prosodic information from it, particularly prosodic cues that relate to word durational patterns. Given the results from the multi-speaker babble feedback condition, thus, it can be also argued that extracting the prosodic information related to word durational pattern

from the choral speech is not a factor in inducing fluency of participants who stutter during choral speech.

A Better Explanation for Fluency Enhancing Effects: Considering Some Extended Cases of Auditory Feedback Conditions

A review of past research suggests that fluency enhancing effects are observed for virtually any kind of choral condition. For example, Barber (1940) showed that participants who stutter read a passage fluently while listening to another speaker who read an entirely different passage. Barber interpreted the finding as supporting the distraction hypothesis; that is, fluency enhancement occurs because the speaker no longer focuses on the speech that he or she is producing, but instead focuses upon the other speaker's voice. This view holds that with the speaker's attention shifted away from stuttered speech, a reduction of stuttering follows. As discussed in the introductory chapter, however, distraction-based explanations have been refuted by many researchers (Fransella, 1967; Fransella & Beech, 1969; Stuart, 1999; Wingate, 1969). Recently, Bloodstein and Nan Bernstein Ratner (2006) expressed their concern about the rather uncritical manner in which the distraction hypothesis is used to account for fluency enhancement in various conditions. They pointed out that the concept of distraction tends to be overused, and that it is vague, with little agreement on the precise operational meaning of the term.

In addition, it has been shown that a fluency enhancing effect has been observed even in more "radical" or "simple" choral reading conditions. For example, Kalinowski et al. (2000) presented a series of vocalized sounds (i.e., a continuous vowel [a], a vowel train [a-i-u], fricative [s]) as choral feedback to speakers who stutter. They examined whether there was a significant change in stuttering frequency of participants who stutter under these conditions. Interestingly, they found that stuttering was significantly reduced in both the continuous vowel condition and the vowel train condition, but not in the fricative condition. Kalinowski et al.

explained the findings by arguing that the fricative [s] is a noise-like sound and it is perceived as less speech-like than the vowel sounds. They concluded that fluency enhancing effects during choral speech are maintained as long as the external choral feedback is perceived as either speech or speech-like sounds.

Kalinowski et al. (2004) attempted to explain the fluency enhancing effects of choral speech by arguing that for fluency to be induced during choral speech, the segmental or prosodic information of the choral speech signal does not necessarily need to be matched with those in the intended speech. Rather, it simply has to present speakers with articulatory gestures (i.e., representations of the co-articulated dynamic trajectories of the human vocal tract). Kalinowski et al. argued that articulatory gestures are invariant objects of speech production and perception (Liberman & Mattingly, 1985; Liberman & Whalen, 2000) and that the presentation of these articulatory gestures of choral speech are necessary to be provided and matched with those in the intended speech.

To explicate neural correlates for the match in articulatory gestures, furthermore, they proposed that a mirror neuron system (Rizzolatti et al., 1988, 1996) acts as the "gestural matchmaker" (Kalinowski & Saltuklaroglu, 2003, p. 342). In their view, the mirror neuron system enables the speaker to link the perception and production of speech gestures. According to Kalinowski et al., when incoming articulatory gestures of choral feedback are matched to one of those gestural cues in the intended speech, the mirror neuron system becomes active and restores central integrity during speech production and eventually, makes it possible for participants who stutter to generate fluent speech. Kalinowski et al. (2000) noted that participants who stutter speak relatively fluently even when receiving visual (non-auditory) choral feedback

(i.e., silent speech). They interpreted the finding to suggest that gestural information of choral feedback has to be provided and matched to those cues in the intended speech.

However, the argument based on the match in gestural cues and the involvement of the mirror neuronal system could be refuted if the finding is considered that participants who stutter did speak as relatively fluently while receiving the multi-speaker babble choral feedback as they did while receiving typical choral feedback (CH-NAF). In particular, Kalinowski and Saltuklaroglu (2003) made one assumption about the relationship between the match in gestural information and a degree of fluency enhancement that is pertinent to this discussion. Specifically, they proposed that a signal is likely to enhance fluency more as the gestural information of that signal becomes closer to the gestural patterns in the intended utterance. As mentioned in Chapter 2, the babble noise was used as a type of altered choral feedback that contained obscured prosodic and segmental cues. Accordingly, it can be assumed that the babble noise also contained very little information about speech gestural cues since the babble signal was created by the combination of multiple speakers' voices (i.e., 8 people). A strong view of the mirror neuron/articulatory gesture hypothesis would predict that participants who stutter do speak less fluently during the multi-speaker babble feedback than they did during unaltered choral feedback (CH-NAF), since it can be assumed that typical choral feedback is a "perfect" signal that contains identical (or nearly identical) gestural patterns to those in the intended utterance. As shown in the present study, however, participants who stutter spoke about as fluently during the babble feedback condition as they did during altered choral feedback condition.

As has been well documented by others (e.g., Andrew et al., 1982), speakers who stutter have experienced fluency enhancing effects in response to certain types of non-speech stimuli

(e.g., rhythmic signals, white noise). Given these observations, it can be argued that an explanation that is based on a strong form of the mirror neuron system may not be a good candidate for clearly explaining fluency enhancing effects that are observed during choral speech.

Fluency Enhancing Effects and Auditory Cortex Activation

Are there other ways to explain the fluency enhancing effects that are observed during choral speech? Noting the fluency enhancing effect observed under various forms of altered auditory feedback (e.g., delayed auditory feedback (DAF), frequency-altered feedback (FAF), masking, choral speech), Max et al. (2004) argued that there is a common role of these auditory stimuli on fluency inducement. Specifically, they argued that these auditory stimuli facilitate activation of the auditory cortex. As shown in a number of brain imaging studies (e.g., De Nil et al., 1998; Fox et al., 1996; Fox et al., 2000), the auditory cortex of speakers who stutter is noticeably de-activated during speech production. According to Max et al., the de-activated auditory cortex can be normalized in response to the external auditory stimuli. As has been demonstrated (Curio et al. 2000; Houde et al., 2002), the auditory cortex does react to the external speech stimuli (i.e., recordings of one's own speech). It has been shown that the auditory association areas that process speech and voice (i.e., the anterior middle temporal gyrus (MTG), anterior superior temporal sulcus (STS)) are particularly activated by voice (Belin, Zatorre, Lafaille, Ahad, & Pike, 2000) and intelligible speech (Scott, Blank, Rosen, & Wise, 2000). Thus, it can be reasonably assumed that the external choral speech would facilitate activation of the auditory cortex.

Even in other fluency enhancing conditions, furthermore, activation of the auditory cortex might be the main mechanism that underlies the fluency enhancing effects of participants who stutter. Using $H_2{}^{15}O$ PET, for example, Stager et al. (2003) investigated the possible common

features of “paced speech” and “singing”. Their findings showed that motor regions of participants who stutter were significantly activated during the two conditions. As well, auditory association areas of participants who stutter were also activated during the conditions. The finding is somewhat surprising in that external auditory stimulation was not presented to participants in the study, yet the participants showed increased activation of the auditory cortex. Stager et al. interpreted the findings to suggest that a common fluency-inducing mechanism is one that involves more effective “coupling” of the auditory and motor systems.

As mentioned earlier, Kalinowski et al. (2000) reported that participants who stutter spoke more fluently during a visual choral reading (i.e., silent speech) task than they did when speaking on their own. In the experimental condition, basically, participants who stutter were instructed to attend to visual speech cues from another speaker, instead of hearing auditory choral speech. Interestingly, it has been shown that the auditory cortex is markedly activated in response to visual perception of a speaker’s silent speech movements (Calvert et al., 1997; Campbell et al., 2001). Thus, it can be argued that activation of the auditory cortex is also the main key to explain the fluency enhancing effects observed during visual choral reading for participants who stutter.

The argument based on the facilitated activation of the auditory cortex for fluency enhancing effects in some speaking conditions could extend to explain the well-reported observation that white noise (i.e., auditory masking) tends to yield less fluency improvement than chorally presented speech signals (e.g., Andrews et al., 1982). The difference in the fluency improvement rate between the two speaking conditions can be accounted for by a difference between the two feedback signals. That is, the choral speech is definitely perceived as speech but white noise is not. As mentioned above, the external speech or speech-like signals (i.e., voice, intelligible speech) have been shown to activate auditory cortex regions, particularly, the anterior

middle temporal gyrus (MTG) and anterior superior temporal sulcus (STS) (Belin et al., 2000; McGuire et al., 1996; Scott et al., 2000). As suggested by Stager et al. (2003), the main role of these auditory areas is to process speech and voice by mainly involving auditory feedback mechanism. It can be argued that the external choral speech can facilitate activation of these auditory cortex regions that process voice and speech. As Stager et al (2003) argued, consequently, more effective auditory monitoring, which may be reflected in increased activity in the auditory cortex, may allow motor areas to control the larynx and the articulators more effectively. Even though there is some evidence to suggest that the secondary auditory cortex is activated by white noise (Paus, Marrett, & Evans, 1996; Paus, Perry, Zatorre, Worskey, & Evans, 1996), it appears that non-speech signals do not directly facilitate activation of the auditory regions that process speech and voice.

In this view, the fluency enhancing effect observed during the multi-speaker babble condition can be explained by arguing that the babble noise facilitates activation of regions of the auditory cortex that are involved in processing speech and voice. Even though the individual spoken words that constitute babble noise are not discernable as a result of the combination of multiple speakers' voices, the signal can be still perceived as a speech or speech-like signal in that it contains some amount of prosodic or segmental information. As long as the incoming signal can be perceived as speech or speech-like signals, as Kalinowski et al. (2000) argued, it can be assumed that the regions of auditory cortex responsible for processing speech and voice can be activated by the external babble noise.

Interpretation of Auditory Cortex Activation Related to a Theoretical Perspective

How can the enhanced activation of the auditory cortex of participants who stutter during choral speech be interpreted in terms of mechanism underlying stuttering? In particular, Max et al. (2004) argued that people who stutter have unstable internal models associated with the

feedback control system. According to Max et al., the auditory cortex is primarily responsible for creating the representations of the internal models associated with the feedback control system.

More specifically, Max et al. proposed that the speech production mechanism consists of two interactive systems, that is, a feedforward (i.e., motor) control system and a feedback (i.e., auditory or sensory monitoring) control system. The former system mainly involves assembling a basic speech motor plan and executing the planned speech motor commands, while the latter system concerns monitoring and correcting the planned speech motor commands based on auditory or sensory feedback information available. Furthermore, the two speech control systems are represented by internal models. According to Max et al., the feedforward control system is represented by internal models to compute the motor commands necessary to achieve a planned speech goal. On the other hand, the feedback control system is represented by internal models to monitor the planned speech commands based on feedback information available. Max et al. thought of stuttering as a deficit in the internal model and argued that the unstable internal models in participants who stutter lead to deactivation of auditory cortex and are eventually normalized with the provision of external auditory stimuli that would increase the activation of the auditory cortex.

As discussed earlier, Stager et al. (2004) showed that motor and auditory regions are co-activated during fluency enhancing conditions (i.e., paced speech, singing) in participants who stutter. They interpreted the finding to suggest that the co-activation of motor and auditory regions may reflect more effective coupling of auditory and motor systems under fluency enhancing conditions. As Stager et al suggested, therefore, more effective auditory monitoring, which may be reflected in increased activity in the auditory cortex, may allow motor areas to control the larynx and the articulators more efficiently.

Fluency Enhancing Effects under DAF and FAF

Significant differences were found in the frequency of stuttering behaviors produced by participants who stutter between NAF and DAF and between NAF and FAF. Stuttering was reduced in participants who stutter during these solo altered reading conditions. As mentioned in Chapter 1, many studies have shown that stuttering is significantly reduced during DAF and FAF, in isolation, as well as during combined DAF and FAF (e.g., Lincoln et al., 2006).Thus, it can be argued that fluency enhancing effects observed during DAF or FAF were replicated in the present study. The fluency enhancing effects were also observed in prosody-altered choral reading conditions (i.e., CH-TAF, CH-PAF) and no significant difference was found in the mean frequency of stuttering behaviors produced by participants who stutter between solo altered reading and prosody-altered choral reading conditions. Thus, it can be argued that participants who stutter speak fluently while receiving altered auditory feedback, regardless of the source for that feedback (i.e., own voice feedback or another speaker's voice feedback).

Speech Rate and Altered Auditory Conditions

In the present study, participants who stutter spoke at a relatively consistent rate across the experimental speaking conditions. No significant change in speaking rate was found in participants who stutter across select pairwise comparisons in the experimental speaking conditions, however. According to a simple inspection of speaking rates across the experimental conditions (shown in Figure 3-2), it appeared that participants who stutter spoke more slowly during the NAF and DAF conditions This would be expected because the participants who stutter produced relatively many repetitions, blocks, and audible prolongations (verbal behaviors that are symptomatic of stuttering) in the NAF condition. However, the finding that participants who stutter spoke slower than nonstuttering participants during NAF conditions but at a relatively consistent rate across the remaining experimental speaking conditions seems to suggest that

participants who stutter attained their fluency during the experimental conditions, in part, by reducing their articulation rate during conditions other than NAF (i.e., during conditions other than NAF, the participants were not spending much time stuttering, yet they took just as long to say the experimental sentences).

The difference in speaking rate on the DAF condition between the two groups was not significant, which indicated that participants who stutter and participants who do not stutter tend to speak slowly during DAF. It has been reported that participants, regardless of their group affiliation (stuttering group vs. non-stuttering group), tend to slow their speech rate during DAF (Bloodstein, 1995). Some researchers (e.g., Wingate, 1969, 1979) have argued that slowed speech rate is the main factor in explaining fluency enhancing effects observed during DAF. However, it has been shown that stuttering can be reduced under DAF without considerable changes in speech rate, or even at increased speech rates (MacLeod, Kalinowski, Stuart, & Armson, 1995). Thus, it can be argued that something other than reduced speech rate under DAF is responsible for fluency improvement (Bloodstein & Bernstein Ratner, 2006). As suggested in the previous section, what seems responsible for fluency improvement observed during DAF can be that the external delayed auditory feedback might enhance activity in the auditory cortex that process speech and voice. Some studies (e.g., Watkins et al., 2008) have shown that delayed or frequency-altered feedback, in comparison with normal auditory feedback, facilitates activation of the superior temporal cortex bilaterally in participants who stutter and participants who do not stutter.

Reading Accuracy and Stuttering Frequency

As shown in the present study, participants who stutter and participants who do not stutter made relatively few reading errors across the experimental reading conditions. Even though the observed number of reading errors for participants who stutter was greater than that for

participants who do not stutter, which was based on the preliminary descriptive analysis of reading errors made by participants who stutter and participants who do not stutter across the experimental reading conditions (shown in the figure 3-5), results of statistical testing showed that the difference was not significant. The Spearman test also showed weak correlation (rho = -.077) between stuttering frequency in NAF and reading error rate in NAF for participants who stutter. Thus, there appeared to be little if any systematic relationship between reading error rate in NAF and stuttering frequency in NAF.

Limitations of the Present Study

Several limitations of the present study should be highlighted. First, the main experiment consisted of a series of sentence reading tasks. Even though many sentences (i.e., 60 sentences in each of the experimental tasks) were used and the participants' stuttering frequency rates were consistent with those in spontaneous conversation samples, the speech production processes used in reading may not be the same as those used in the spontaneous conversational speech. The finding that participants overall stuttering frequency while producing these sentences was consistent with conversational samples was somewhat unexpected because it has been reported that participants who stutter often stuttered less frequently during typical oral reading (NAF) than they do during conversational speech (Bloodstein, 1995).

Use of a reading task was deemed necessary for the present study, because of the need to systematically manipulate prosodic cues (i.e., word durational pattern, pitch contour). Such manipulations would not have been very feasible had spontaneous conversational speech been used. In future research, however, it might be worthwhile to develop simple non-reading tasks that yield some control over sentence form and content (e.g., spontaneous sentence generation in response to a modeled sentence). Another possibility is to create oral reading tasks that feature

added time pressure. Such methodological adjustment would likely increase the frequency of stuttering, particularly during NAF conditions.

A second limitation of the present study is that this study had relatively small sample size (i.e., 8 participants who stutter and 8 participants who do not stutter). As discussed earlier, the small sample size made it difficult to meet normality assumption for the stuttering frequency data. Thus, nonparametric statistical methods, such as Mann-Whitney U test, Friedman test, and paired sample Wilcoxon signed rank test, were used to complete all of the analyses for the present study. One of the main criticisms against such nonparametric approaches is that they have less power than their parametric counterparts (Schiavetti & Metz, 2002). Had the sample size been larger, findings from the present study might have been somewhat different. Thus, future research needs to be conducted on this topic using more participants.

A third limitation of the present study is that method used for the reference point entrainment could be made more sophisticated. As shown in Chapter 2, five distinct phones located at different locations (i.e., sentence-initial, 3 different sentence-medial, sentence-final) were chosen for the reference point analysis. It is possible that choosing only five phones as the reference points provided a limited view of the extent to which the speech of participants who stutter corresponds with choral speech model. Thus, a more sophisticated method (e.g., moment by moment (or syllable by syllable) entrainment) should be developed for further entrainment analysis.

Lastly, as discussed above, several of the participants who stutter spoke relatively fluently during typical solo reading condition (NAF). Most of the participants reported themselves as mild stutterers. Other participants who present moderate or severe stuttering need to be recruited

so that the findings can be generalized more readily to the broad population of people who stutter.

Concluding Remarks and Future Studies

As pointed out by Bloodstein and Bernstein Ratner (2006), many studies on effects of altered auditory feedback have been conducted in laboratory settings using tasks that are somewhat different from those of everyday life. Relatively few studies have been done in the context of conversation (Lincoln et al., 2006). Several studies have utilized monologue (Armson & Stuart, 1998; Natke, Grosser, & Kalveram, 2001; Stuart et al., 2004) as the main task and found no significant difference in stuttering frequency between a baseline NAF condition and altered auditory conditions (e.g., FAF). Some studies (Zimmerman et al., 1997) have utilized quasi-conversational tasks (e.g., scripted telephone conversation) and have shown that participants who stutter experienced significant reductions in stuttering, suggesting that altered auditory feedback effects do indeed generalize to conversational contexts. As Lincoln et al. (2006) commented, however, such studies are still somewhat limited because they do not directly replicate what participants who stutter encounter during typical daily settings. To explicate the impact of altered auditory feedback on stuttering frequency, therefore, more studies need to be done using non-reading tasks such as monologue and conversational speech.

As noted by Stager et al. (2003), furthermore, more brain imaging studies need to be conducted to investigate if there is a common brain region(s) that may be selectively activated by various altered auditory feedback conditions. As discussed earlier, activation of the auditory cortex may be a primary mechanism in explaining fluency enhancing effects during various types of altered auditory feedback, including choral speech. In order to be able to test this hypothesis, more brain imaging studies need to be conducted by including as various fluency enhancing procedures as possible.

To further understand the role of auditory feedback signals on fluency improvement of participants who stutter, lastly, more studies need to be conducted using various other types of auditory signals, such as backward speech, non-native speaker's choral speech, and music with and without lyrics. In addition, some other types of sensory signals (e.g., tactile, vibro-tactile), presented either periodically or quasi-periodically, can be also used to examine if fluency enhancing effect are observed under non-auditory rhythmic signals. As discussed earlier, participants who stutter have been shown to speak more fluently during visual choral speech (i.e., watching lipped speech) and auditory regions of the participants who stutter that process voice and speech are activated during the condition (Kalinowski et al., 2000). Interestingly, it has been shown that the auditory cortex can be also activated in response to visual perception of nonspeech movements that can be interpreted as speech movement (Campbell et al., 2001). Thus, future studies need to be done using some other visual stimuli, such as different (or incongruous) visual speech movement or nonspeech movements that can be assumed as speech movement.

In conclusion, it can be argued that, as of now, there is no clear-cut explanation for the fluency enhancing effects that are observed during altered auditory feedback. There is, however, no shortage of hypothesized explanatory mechanisms. More than a few researchers have attempted to solve the puzzle of fluency enhancing effects observed during various altered auditory feedback conditions, hoping to find a clear-cut explanation for the phenomenon and eventually, explicate fully the mechanism underlying stuttering. As mentioned above, more studies in the future need to be conducted to fully understand the mechanism underlying fluency enhancing effects observed during various altered auditory feedbacks. Most of this line of research documented so far has been conducted within laboratory contexts. It can be argued that

durable fluency benefits need to be more documented from out-of-laboratory and long-term studies and therapeutic intervention needs to be guided based on fluency improvement documented by those studies as well.

APPENDIX A
CASE HISTORY QUESTIONNAIRE

Name:	Date of Birth:
Age:	Sex: □ Male □ Female
Today's Date: ____/____/____	Telephone number:
Native Language(s):	
Other Language(s):	Competence Level:□ Poor □ Good □ Excellent
Highest Education Level:□ High school □ Associate's Degree □ Some College □ Bachelor's Degree □ Graduate Degree (MA, Ph. D.) □ Other:_____	
Email address:	

Medical, Developmental, & Family History

1. Do you currently have a speech or language problem?□ Yes □ No

If yes, what type of problem?

2. Please indicate any history of significant injuries, illness, or developmental problems, particularly those that might affect your ability to communicate):

3. Do you feel you have normal hearing?□ Yes □ No
If no, describe:

4. Do you have normal vision?□ Yes □ No
If no, describe:

5. Do you have normal reading skills?□ Yes □ No
If no, describe:

6. Have you ever had a speech and language evaluation?□ Yes □ No

If yes, when, where, and what were the results?

7. Have you had any treatment for speech and language problems in the past?
□ Yes □ No

If yes, what type(s) of treatment(s)?

8. Do any of your family members have communication impairments such as stuttering, or language or reading disability?□ Yes □ No

If yes, please describe:

Early Stuttering

9. Do you stutter?□ Yes □ No (If yes, answer the following questions 10 through 25.)

10. At which age was your stuttering first noticed? _____

11. Who first noticed or mentioned your stuttering?
□ Parent □ Sibling □ Teacher □ Other close relative □ Other _____

12. What did your speech sound like when the problem first began? How did you appear to others when you first began to stutter?

13. Please describe any situations or conditions that you associate with the onset of your stuttering.

14. Since the onset of stuttering, how have the symptoms of your stuttering changed?

□ Increase in the severity of stuttering □ Decrease in the severity of stuttering
□ Increase in the amount of disfluency □ Decrease in the amount of disfluency
□ Increase in amount of verbal participation □ Decrease in amount of participation
□ Increase in speech-related anxiety□ De crease in speech-related anxiety

15. Since the onset of stuttering, what coping devices have you developed for stuttering?

□ Changing the loudness of speech □ Changing the pitch of voice
□ Using a slower rate of speech □ Using a faster rate of speech □ Avoiding words
□ Looking away from the listener
□ Using rhythmic movements of fingers, arms, legs etc to aid fluency
□ Pretending to forget an answer □ Other(s):

Current Stuttering

16. Do you ever experience excessive tension or tightness when you stutter? If so, where?
□ Tongue □ Lips □ Chest □ Diaphragm □ Throat □ Other_____

17. Which of the following best describes the way that you stutter now?

□ Occasional brief breaks in speech fluency
□ Occasional lengthy breaks in speech fluency
□ Frequent brief breaks in speech fluency
□ Frequent lengthy breaks in speech fluency
□ Other(s):

18. At present, how severe do you think your stuttering is?

□ Very mild
□ Mild
□ Moderate
□ Severe
□ Very severe

19. Do you currently avoid speaking because of stuttering?
□ Yes □ No If "yes", describe:

20. Are there any particular words that you stutter upon often?
If yes, please describe:

21. Are they any particular situations in which you stutter often?
If yes, please describe:

22. What is your reaction to the way or the amount that you stutter now?

□ Awareness that speech is different □ Surprise □ Indifference □ Anger or frustration □ Fear of stuttering again □ Shame □ Anxiety □ Embarrassment
□ Other(s):

23. Have you had any treatment for stuttering (either formally or informally)?

If yes, what type(s) of treatment(s)?

24. How often do you stutter when ____?

	Not at all		Somewhat		Very much
Talk to young children	1	2	3	4	5
Answer direct questions	1	2	3	4	5
Use new words that are unfamiliar	1	2	3	4	5
Read out loud	1	2	3	4	5

Ask questions	1	2	3	4	5
Speak when tired	1	2	3	4	5
Talk to family members	1	2	3	4	5
Say your name	1	2	3	4	5
Talk to adults/teachers	1	2	3	4	5
Use the telephone	1	2	3	4	5
Recite memorized materials	1	2	3	4	5
Talk to strangers	1	2	3	4	5
Speak when excited	1	2	3	4	5
Talk to friends	1	2	3	4	5

25. Do you feel that stuttering interferes with your _____?

	Not at all		Somewhat		Very Much
Daily life	1	2	3	4	5
Social relationships	1	2	3	4	5
School performance	1	2	3	4	5
Work performance	1	2	3	4	5
Overall quality of life	1	2	3	4	5

APPENDIX B
THE SCRIPT FOR THE EXPERIMENT

Main experiment [Order of presentation of conditions will be randomly determined]

A Choral reading condition

OK. Now, it is time for the experiment. Basically, all you need to do is to read aloud each of sentences on the computer screen. Prior to each sentence you will hear a brief introduction: "The sentence you have to read is…" Wait until the introduction is complete and then begin reading the sentence. While you are reading, you will hear another speaker's voice, saying the same sentence (i.e., choral speech). You may read the sentences at whatever pace is most comfortable for you. Sometimes you may be reading right along with the other speaker. At other times you may be reading faster than the other speaker or slower than the other speaker. Choose whatever rate of speech is most comfortable for you. We will begin with some practice sentences. [Just let participants practice the trial versions so they can see what the experiment is all about.] Feel free to ask any questions that you have while doing the practice sentences.

B. Prosody-altered conditions [=Duration or Pitch Contour]

Once again, all you need to do is to read aloud each of sentences on the computer screen. Prior to each sentence you will hear a brief introduction: "The sentence you have to read is…" Wait until the introduction is complete and then begin reading the sentence. While you are reading, now, you will hear some sentences that may sound distorted through earphones. You may read the sentences at whatever pace is most comfortable for you. Sometimes you may be reading right along with the other speaker. At other times you may be reading faster than the other speaker or slower than the other speaker. Choose whatever rate of speech is most comfortable for you. We will begin with some practice sentences. [Just let participants practice the trial versions so they can see what the experiment is all about.] Feel free to ask any questions that you have while doing the practice sentences.

C. Normal reading condition

Once again, all you need to do is to read aloud each of sentences on the computer screen. Prior to each sentence you will hear a brief introduction: "The sentence you have to read is…" Wait until the introduction is complete and then begin reading the sentence. While you are reading, now, you will not hear any sentences or nothing through earphones. You may read the sentences at whatever pace is most comfortable for you. Sometimes you may be reading right along with the other speaker. At other times you may be reading faster than the other speaker or slower than the other speaker. Choose whatever rate of speech is most comfortable for you. We will begin with some practice sentences. [Just let participants practice the trial versions so they can see what the experiment is all about.] Feel free to ask any questions that you have while doing the practice sentences.

D. Babble condition

Once again, all you need to do is to read aloud each of sentences on the computer screen. Prior to each sentence you will hear a brief introduction: "The sentence you have to read is…" Wait until the introduction is complete and then begin reading the sentence. While you are reading, now, you will hear the voices of several other speakers. It sounds like crowded room. You may read the sentences at whatever pace is most comfortable for you. Sometimes you may be reading right along with the other speaker. At other times you may be reading faster than the other speaker or slower than the other speaker. Choose whatever rate of speech is most comfortable for you. We will begin with some practice sentences.

[Just let participants practice the trial versions so they can see what the experiment is all about.] Feel free to ask any questions that you have while doing the practice sentences.

D. DAF

Once again, all you need to do is to read aloud each of sentences on the computer screen. Prior to each sentence you will hear a brief introduction: "The sentence you have to read is…" Wait until the introduction is complete and then begin reading the sentence. While you are reading, now, you will hear some sentences that sound like echo of your voice. You may read the sentences at whatever pace is most comfortable for you. Sometimes you may be reading right along with the other speaker. At other times you may be reading faster than the other speaker or slower than the other speaker. Choose whatever rate of speech is most comfortable for you. We will begin with some practice sentences. [Just let participants practice the trial versions so they can see what the experiment is all about.] Feel free to ask any questions that you have while doing the practice sentences.

E. FAF

Once again, all you need to do is to read aloud each of sentences on the computer screen. Prior to each sentence you will hear a brief introduction: "The sentence you have to read is…" Wait until the introduction is complete and then begin reading the sentence. While you are reading, now, you will hear some sentences that sound like another speaker's voice of relatively high tone. You may read the sentences at whatever pace is most comfortable for you. Sometimes you may be reading right along with the other speaker. At other times you may be reading faster than the other speaker or slower than the other speaker. Choose whatever rate of speech is most comfortable for you. We will begin with some practice sentences. [Just let participants practice the trial versions so they can see what the experiment is all about.] Feel free to ask any questions that you have while doing the practice sentences.

APPENDIX C
PASSAGE 1-5

Passage 1

There are many different species of sparrow. This very small bird is found throughout the world. There are about fifty different species of sparrows living in North and South America. Sparrows are only about four to six inches in length. Many people appreciate their beautiful song.

Sparrows prefer to build their nests in low places. Their nests are usually built on the ground, or in clumps of grass, low trees, and low bushes. In cities, they build their nests in building nooks and other holes. They rarely build their nests in high places. Sparrows build their nests out of twigs, grasses, and plant fibers. Their nests are usually small and well-built structures.

Female sparrows lay four to six eggs at a time. The eggs are white with reddish brown spots. The eggs hatch within eleven to fourteen days. Both the male and female parents care for the young. Insects are fed to their young after hatching. Young sparrows are ready to leave the nest eight to ten days after hatching. The large feet of the sparrow are used for scratching seeds. Adult sparrows mainly eat seeds.

Sparrows can be found almost anywhere there are humans. Some species of sparrows prefer to live in deserts, prairies, swamps, marshes, forests, and other bushy areas. Some sparrows in northern North America will migrate south in winter, although most stay in one area year-round. The older adult males of the migrating sparrows usually spend their winters near their breeding area. Many people throughout the world enjoy these delightful birds.

Passage 2

The Roman Emperor Claudius II was fighting many wars. He wanted a strong army, but many men did not want to be soldiers. Claudius thought the men wanted to stay home to be with their wives and children instead of leaving to fight wars. Claudius thought of an awful solution to his problem. He decided to cancel all marriages! No one in all of Rome could get married. Claudius thought that if the men couldn't get married, the men would ignore the women and want to be soldiers.

Valentine, who was a priest, believed that people needed to get married. He thought that if they were not married, they would be tempted to sin by living together without being married. So he secretly and illegally married couples anyway! He performed the weddings in secret places, so the Roman soldiers would not find out. But they did find out. Valentine was arrested and brought before the Emperor. The Emperor thought Valentine was a well spoken and wise young man, and encouraged him to stop being a Christian and become a loyal Roman. Valentine would not deny his beliefs, and he refused. He was sent to prison until he could be executed. While he was in prison, he sent out letters to his friends and asked to be prayed for by writing *Remember your Valentine*. Valentine was killed on the 14th or the 24th of February in the year 269 or 270. We celebrate Valentine's Day on February 14th in honor of St. Valentine.

Passage 3

Over 35,000 different species of spiders live almost everywhere in the world. The only places you can't find spiders are on the tops of mountains, in the ocean and at the poles. Spiders are *carnivorous*. That means that they eat only meat. They eat insects and sometimes other spiders. Some spiders eat other animals such as small fish, lizards, frogs, baby birds and mice. Most spiders use poison to kill or paralyze their prey. All spiders have poison, and to a small insect all spiders are very dangerous, but only a few spiders have poison strong enough to hurt people.

Spiders that bite and cause pain to humans are called *medically significant* spiders. This means that they have enough venom (poison) to cause a serious bite that will need to be looked at by a doctor. Some of the poisonous spiders found in North America include the black widow, the brown recluse, the hobo spider, and the yellow sac spider.

There are about 6 different species of black widow spiders. Three of these species are found in the warm southern United States. Black widow spiders build webs, and they live wherever they can build one. They rarely live in houses and other buildings, but if the weather gets very cold, they can move inside. Black widow spiders eat insects, and stay in their webs to catch them. Only the female black widow spider is dangerous. She is considered to be the most venomous spider in the United States!

Passage 4

Hibernation is one of the main adaptations that allow certain northern animals to survive long, cold winters. Hibernation is like a very deep sleep that allows animals to save their energy when there is little or no food available. The body functions of 'true hibernators' go through several changes while they are hibernating. Body temperature drops, and the heart rate slows. For example, a hibernating woodchuck's body temperature drops by more than 30 degrees Celsius, and its heart rate slows from 80 to 4 beats per minute! Other true hibernators include the jumping mouse, little brown bat, eastern chipmunk, and several ground squirrels.

Other animals, such as the skunk and raccoon, are not considered true hibernators, as they wake up in the winter to feed, and their body functions do not change as much. Since they only sleep for a little bit at a time, the term *dormancy* or 'light sleeping' is used to describe their behavior. The largest animals to hibernate are bears. Their heart rate may slow down from a usual 40 –50 beats per minute to 8-12 beats per minute, but their body temperature changes very little, so they are able to wake up quickly.

Hibernating animals have a special substance in the blood called *hibernation inducement trigger*, or HIT. This substance becomes active in the fall, when the days become cooler and shorter. When HIT becomes active, the animals start preparing for winter. Some animals store food so that they can eat when they wake up, and some animals eat a lot in late summer and fall to add excess fat to their bodies.

Passage 5

Before there was a game called baseball, Americans had discovered the fun of swinging a stick at a ball. In the early 1800s, children held tree limbs above their shoulders and swatted at walnuts wrapped in rags. Adults swung at balls with the same enthusiasm. Broomsticks made great bats, as did large pieces of wood called "wagon tongues," named after the part of a wagon that jutted out and held the horses' reins. If players had the skill and time, they carved and sanded pieces of ash or hickory into long, graceful bats. Sometimes the bats were painted with a faux (false) grain to imitate the look of expensive woods and then used as trophies of good games. Balls were also made by hand, of rags, pieces of old mattress fabric, or horsehide.

The simple equipment made it possible to play "ball" almost anywhere. Soldiers enjoyed a game at Valley Forge during the Revolutionary War, and the Indian leader Geronimo fielded a team of Apaches against the U.S. Army at Fort Sill, Oklahoma, in the late 1800s. The Apaches won.

In the 1840s and 1850s, thousands of ambitious young men left their families in Europe and immigrated to New York. They took jobs as policemen, firemen, and shipbuilders, and discovered baseball. Many of the immigrants were proud to be Americans and they wanted to play the American game. Teams evolved out of the different professions. Shipbuilders pitched to firemen. Undertakers caught fly balls hit by doctors. Schoolteachers tagged out bartenders on fields and lots around the city.

Passage 6

When the sunlight strikes raindrops in the air, they act as a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow. Throughout the centuries people have explained the rainbow in various ways. Some have accepted it as a miracle without physical explanation. To the Hebrews it was a token that there would be no more universal floods. The Greeks used to imagine that it was a sign from the gods to foretell war or heavy rain. The Norsemen considered the rainbow as a bridge over which the gods passed from earth to their home in the sky. Others have tried to explain the phenomenon physically. Aristotle thought that the rainbow was caused by reflection of the sun's rays by the rain. Since then physicists have found that it is not reflection, but refraction by the raindrops which causes the rainbows. Many complicated ideas about the rainbow have been formed. The difference in the rainbow depends considerably upon the size of the drops, and the width of the colored band increases as the size of the drops increases.

APPENDIX D
THE EXPERIMENTAL SENTENCES

The 20 Sentences

The policeman and detective had ticketed the Canadian by mistake.
The carpenter and mechanic would repair the bicycle for nothing.
The composer and teacher had directed the musical from September.
The counselor and therapist had conversed with Jonathan by telephone.
The bachelor and musician will perform the comedy of Shakespeare.
The senator and director will conclude the meeting by tomorrow.
The director of Patriot will donate the valuables to Benjamin.
The governor of Colorado will pardon the lawbreaker by Tuesday.
The candidate for Congress was discussing his concerns with Democrats.
The chairman of Microsoft might compliment the volunteer for helping.
The reporter from Tennessee will correspond with Jonathan by Tuesday.
The chancellor from Cambridge could disappoint the people by resigning.
The member of Parliament may consider the suggestion from Timothy.
The gentleman with diabetes will welcome the physician from Chicago.
The children with Benjamin will perform the musical on Saturday.
The passenger from Baltimore will compliment the captain from Boston.
The historian from Kentucky will publish the biography on Thursday.
The governor of Tennessee will continue the discussion on Saturday.
The technician from Toshiba is purchasing the materials from Gateway.
The detective from Germany is searching for someone from Columbia.

The 40 Other Sentences

The athlete who ran for student government selected his running mates.
Is the price of the parking decal for motorcycles reasonable?
Please join our village and resident director for the meeting tomorrow.
The neighborhood residents will be talking about their primary concerns.
Would you rather study mathematics or chemistry next summer semester?
The journalism majors decided to form a new student newspaper.
Most college students are unwilling to enroll in early-morning classes.
Philadelphia scored eleven straight points in the fourth quarter and won.
Today's temperatures will reach seventy-nine degrees by early afternoon.
Many graduate students will receive scholarships to pay for tuition.
Fortunately, Jonathan could get a job as a restaurant manager.
Mr. Peters argued that children deserve quality health insurance coverage.
All international students needed to buy health insurance before next month.
The analyst reported that the football team recruited a wealth of talent.
Did the candidate quit the race after losing in the primary?
Christopher promised me he would review the problem before Saturday.
Why was Barbara forced to end her vacation in California early?
The federal legislators worked so hard to develop an anti-gang law.
The police officer ordered the crowd to step back immediately.

Everyone knew Pamela was the most brilliant student in the class.
Our views aren’t always the same as those of the television station.
Jennifer chose the public university because her friend enrolled there.
Did the Japanese student travel overseas to Thailand last month?
Paul Davenport said that the windstorm left at least eleven people homeless.
I predict the candidate won't be elected because he is too arrogant.
People always appreciate it when they receive good customer service.
Please don't touch or move the merchandise without first asking permission.
Studies on the effects of alcohol have had negative results.
Did Timothy really sell twenty-two automobiles to the local dealer?
Introduction to Communication was one of the most popular classes.
The Germans now realize that reunification has come with problems.
Allison wondered whether linguistics was really a branch of psychology.
If Timothy goes swimming again, he certainly will catch a cold.
The incident just occurred, before anyone knew what was happening.
Did Mark go immediately to the embassy when his passport was stolen?
Jonathan asked, "was Catherine on the soccer team last semester?"
Melody enjoyed painting more than any of her other hobbies.
The applications for these positions are available at the desk.
The committee recommended several ways to cut the college's budget.
Is Mr. Williamson living in the western part of Mississippi?

APPENDIX E
WORKSHEET FOR MEASUREMENT

WorkSheet				
Subject Code _____		Date _____/_____/_____		
#	Normal Condition	Accuracy	Fluency	Rate
1	I predict the candidate won't be elected because he is too arrogant.			
2	Did the Japanese student travel overseas to Thailand last month?			
3	Did Mark go immediately to the embassy when his passport was stolen?			
4	The children with Benjamin will perform the musical on Saturday.			
5	The applications for these positions are available at the desk.			
6	The technician from Toshiba is purchasing the materials from Gateway.			
7	Please don't touch or move the merchandise without first asking permission.			
8	Jennifer chose the public university because her friend enrolled there.			
9	The composer and teacher had directed the musical from September.			
10	Mr. Peters argued that children deserve quality health insurance coverage.			
11	The governor of Colorado will pardon the lawbreaker by Tuesday.			
12	Studies on the effects of alcohol have had negative results.			
13	The candidate for Congress was discussing his concerns with Democrats.			
14	The athlete who ran for student government selected his running mates.			
15	The director of Patriot has donated the valuables to Benjamin.			
16	Philadelphia scored eleven straight points in the fourth quarter and won.			
17	The federal legislators worked so hard to develop an anti-gang law.			
18	The analyst reported that the football team recruited a wealth of talent.			
19	Please join our village and resident director for the meeting tomorrow.			
20	Our views aren't always the same as those of the television station.			
21	The committee recommended several ways to cut the college's budget.			
22	Why was Barbara forced to end her vacation in California early?			
23	The neighborhood residents will be talking about their primary concerns.			
24	All international students need to buy health insurance before next month.			
25	Everyone knew Pamela was the most brilliant student in the class.			
26	The chancellor from Cambridge could disappoint the people by resigning.			
27	Is the price of the parking decal for motorcycles reasonable?			
28	The police officer ordered the crowd to step back immediately.			
29	Introduction to Communication was one of the most popular classes.			
30	Is Mr. Williamson living in the western part of Mississippi?			
31	Melody enjoyed painting more than any of her other hobbies.			
32	The passenger from Baltimore will compliment the captain from Boston.			

33	Christopher promised me he would review the problem before Saturday.			
34	The historian from Kentucky will publish the biography on Thursday.			
35	Would you rather study mathematics or chemistry next summer semester?			
36	Paul Davenport said that the windstorm left at least eleven people homeless.			
37	The governor of Tennessee will continue the discussion on Saturday.			
38	The journalism majors decided to form a new student newspaper.			
39	The incident just occurred, before anyone knew what was happening.			
40	The detective from Germany is searching for someone from Columbia.			
41	Allison wondered whether linguistics was really a branch of psychology.			
42	Fortunately, Jonathan could get a job as a restaurant manager.			
43	The gentleman with diabetes will welcome the physician from Chicago.			
44	The carpenter and mechanic would repair the bicycle for nothing.			
45	Jonathan asked, “Was Catherine on the soccer team last semester?”			
46	The member of Parliament may consider the suggestion from Timothy.			
47	People always appreciate it when they receive good customer service.			
48	The policeman and detective had ticketed the Canadian by mistake.			
49	The Germans now realize that reunification has come with problems.			
50	The bachelor and musician will perform the comedy of Shakespeare.			
51	Many graduate students will receive scholarships to pay for tuition.			
52	The senator and director will conclude the meeting by tomorrow.			
53	If Timothy goes swimming again, he certainly will catch a cold.			
54	The counselor and therapist had conversed with Jonathan by telephone.			
55	Did the candidate quit the race after losing in the primary?			
56	Did Timothy really sell twenty-two automobiles to the local dealer?			
57	Today’s temperatures will reach seventy-nine degrees by early afternoon.			
58	The chairman of Microsoft might compliment the volunteer for helping.			
59	Most college students are unwilling to enroll in early-morning classes.			
60	The reporter from Tennessee will correspond with Jonathan by Tuesday.			

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BIOGRAPHICAL SKETCH

Jin Park has earned an M.A. degree in linguistics with an emphasis on phonology at Sogang University, Seoul, South Korea in 1998. Jin began his doctoral program at UF by studying linguistic theories and applied areas of linguistics in 2000. Overtime, however, Jin realized that he aspired to do something more practical through which he can give people in need real help. Jin became interested in communication sciences and disorders and eventually chose the discipline as his new profession.

After transferring to the new program, Jin took several basic undergraduate courses, more advanced doctoral courses, and basic and advanced courses on research design and statistical methods. Under the supervision of his advisor Dr. Logan Kenneth, especially, Jin also did research project with Korean bilingual preschoolers. Later, Jin presented the results of the bilingual study in poster session of the ASHA annual convention (2004). Recently, Jin also presented some preliminary results of his dissertation project in the poster session of the ASHA annual convention (2008).

Upon completion of his Ph.D. program, Jin plans to continue developing his skills as researcher. After that, Jin will go back to his country to teach at the university level and develop treatment programs for local speech and language clinics.